



ENVIRONMENTAL OPTIMIZATION IN NEW URBAN  
DESERT COMMUNITIES

A CASE STUDY OF THE STUDENT HOUSING UNITS IN  
THE NEW AMERICAN UNIVERSITY IN CAIRO CAMPUS

BY

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## Abstract

Recent forecasts show continuing strong growth for worldwide energy demand over the next few years. However, while developed countries are beginning to decouple their energy consumption from economic growth (through structural reforms and increases in energy efficiency), there remains a strong direct relationship between energy consumption and countries with developing economies.

Egypt, which is regarded as one of the countries with developing economies, has taken strong strides in economic reform in a relatively short period. After successful macroeconomic stabilization reforms in the early 1990s, Egypt solidified its position as middle-income country with one of the largest and strongest economies on the African continent. Unfortunately, there is an energy price for this development. As Egypt's economy grows, so does its energy consumption rate in different development sectors.

One of the sectors that is recently witnessing a boom is the building sector, driven by international and local investments fuelling the development of new urban communities in the form of new cities in the desert, along with the government's efforts to provide housing opportunities for the exploding population in the capital by increasing the number of housing projects.

Unfortunately the majority of the new desert development lacks concern for the preservice of the environment and energy sources as there is no real enforcement of building regulations that dictate energy efficiency. If the current practice remains, the increasing energy consumption from the building sector threatens to significantly deplete a large percentage of the country's non-renewable energy sources.

Even though the majority of the past projects built lack environmental optimization, a few individual projects have attempted to set the example and take the position of pilot projects for future sustainable urban desert development.

One of these projects is the new American University in Cairo campus in new Cairo. One of the main objectives of the relocation of the university from its previous downtown location to the desert of new Cairo was to achieve environmental optimization and reduce energy costs.

The campus design team attempted to reduce Energy loads by applying measures such as properly orienting and massing buildings, coordinating building programming and organization, correctly shading and insulating buildings, using appropriate materials and equipment, relying on natural ventilation, capturing night time and evaporative cooling opportunities

This study attempts to examine the effectiveness of the environmental design strategies applied to the campus in providing internal thermally comfortable conditions using minimal energy consumption. A prototype of a building unit from the student housing parcel was selected for a case study.

Using T.A.S, building thermal simulation software, a parametric study was carried out where Passive design techniques were tested one at a time against a base line case to quantify their impact on internal Temperatures individually.

The results show that the energy consumption of 31,046 kwh/year resulting from the annual mechanical air conditioning of the building could be mitigated through the following measures:

- Utilizing night ventilation through exposing the internal thermal mass of the building to cool night air through a climatically responsive window schedule.
- Shading the unit from surrounding buildings.
- changing the orientation of the building.
- Installing a retractable light tensile structure to cover the unit's external courtyard during the summer.
- Adding stone cladding to the external walls.
- Changing the colour of the external wall.
- Adding insulation to the building envelope.
- Adding & sizing windows in rooms to allow for cross ventilation.
- Substituting existing window shading elements with retractable awnings.

Other campus wide strategies environmental optimization strategies were then examined and it was found that increased comfort could be achieved by integrating strategies such as the thermal unit concept, Landscaping and evaporative cooling.

The integration of renewable energies were then utilized to provide for other energy requirements of the building.

Solar heating panels and Photovoltaics were found to provide all the necessary annual energy needs for supplying hot water, electricity and electrical equipments

Which were found to be **44,820 kwh/year** and **19,922 kwh/year** respectively.

Finally the study concludes by looking into the reasons that prevent the wide practice of environmental design and the integration of renewable energies and suggests possible ways to remove current barriers such as:

- Improving on and implementing building codes and regulations that dictate specific energy consumption standards for different building types.
- Increasing awareness among building users through campaigns and know how between - architects through courses, seminars and workshops.
- Providing grants for renewable energy use.

# CHAPTER. 1: INTRODUCTION

## 1. Introduction

### 1.1 Aim of study

In the annual 'Doing Business' report, Egypt was dubbed as the top economic reformer for 2006/07, improving in 5 of the 10 areas studied. (Doing business report, 2006/2007). Egypt's economic reforms resulted in the facilitation of business starting procedures, reducing the minimum capital requirement from 50,000 Egyptian pounds to 1,000 and halving start-up time and cost. Fees for registering property were reduced from 3% of the property value to a low fixed figure. These factors contributed in significant economic growth in a relatively short time period. (Doing Business report, 2008)

Figures released by the Egyptian government said growth is at 7.1%. (Egypt state information service, 2005) As oil prices have risen, and as oil rich neighbours poured their revenue into Egypt, the country's economy rose. Foreign investment in 2006 was \$5.4 billion, making Egypt the second largest F.D.I (foreign direct investment) recipient in Africa. (World investment report, 2006)

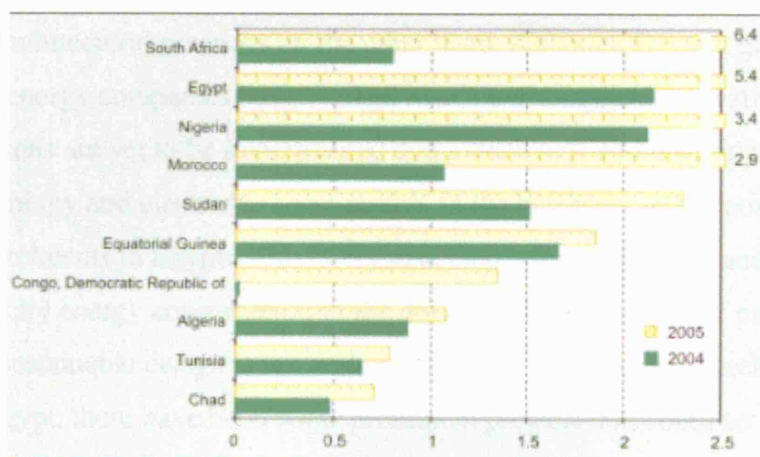


Figure 1: Africa: FDI inflows, top 10 economies, 2004-2005 (World investment report, 2006)



Egypt's economy has grown dramatically after going through a deep recession around the late nineties. Investment in Egypt has increased both in relative and absolute terms. In addition, the FDI has jumped from \$500 million in 2001 to \$11.3 billion in 2007 amounting to 9% of GDP (carnegie middle east center, 2007) This boom has influenced the growth of all development sectors including the building and construction industry.

Unfortunately, this development resulted in an aggressive demand on the country's energy and environmental resources.

With population size of about 65 million in 2001, driving the growth of the construction of housing projects, the buildings sector consumes 19.2% of the total energy consumption, and about 39.1% of the total electricity consumption, which produces 10% of the total CO<sub>2</sub> emissions. (Badran et al, 2003)

In most developed countries today; sustainable development has been taken into account throughout recent housing development projects. In Egypt, a large number of housing projects are being built, but unfortunately environmental and energy aspects aren't taken into consideration.

This is mainly due to two reasons: lack of restricting thermal specifications in the governmental building codes on one hand, and lack of environmental awareness among local architectural practices on the other hand. Although Egypt's government and its major energy companies have worked to achieve energy conservation, large scale applications are yet to be implemented due to technical and institutional barriers.

The current energy and electricity consumption in the buildings sector poses a challenge to architects in Egypt. This is because their way of planning and design influence directly energy consumption in the design and construction of projects. Even though sustainable design is not widely applied in contemporary architectural practices in Egypt, there have been some prominent projects that could set the trend for future development.

The purpose of this paper is to analyze the energy consumption and environmental optimization strategies applied on the housing facilities of the recently constructed new American University in Cairo campus, which is regarded as one of the pilot projects for sustainable design in Egypt. The thermal and energy assessment intends examine the effectiveness of the passive and energy efficient strategies implemented in the design.

## 1.2 Structure of paper

The second chapter of the paper covers the global energy and climatic issues that dictate the necessity for sustainable design applications and strategies. The energy Situation in Egypt is then analyzed in the third chapter, defining possible consequences of the current energy consumption rate on the various local development sectors.

The building sector is then assessed to define its contribution to the energy consumption process, defining the necessity of implementing sustainable design principles in new urban communities being developed in the desert.

The fourth chapter of the paper looks into the climatic conditions of Egypt and defines the targeted thermal comfort zone for occupants in buildings, followed by a review of adequate passive design and energy reduction strategies applicable in buildings in the hot-dry climate of Egypt in the fifth chapter.

The fifth chapter covers the methodology, focusing on the new American university in Cairo campus as one of the pilot projects in environmental optimization in new desert developments and defining its general passive design.

A parametric study of various low energy measures is then conducted on the student housing units to study possible energy reduction scenarios.

Lastly, renewable energy applications are then tried out to respond to the annual energy needs of water heating, lighting and electrical equipments.

The paper ends by an interpretation and analysis of the study, reviewing the limitations of applying sustainable design and Suggesting future scenarios for improving the energy efficiency of the building sector.

2070-2100 Prediction  
vs 1960-1990  
Average

# CHAPTER.2: THE GLOBAL ISSUES OF SUSTAINABILITY

Based on HadCM3

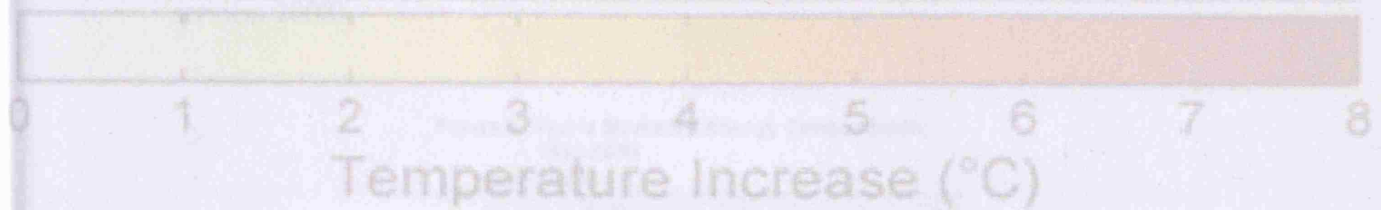


Figure 2: World market energy consumption in 2004/05, base  
press version 2005

The report also indicates that from 41.8 percent in 2005 to 54.8 percent in 2030 is the new OECD consumption for world consumption.

Even the sustained high world oil prices that are anticipated to persist over the long term, the world 113 percent a barrel and 180 dollars a barrel will not halting the rate of sustained a current every year.

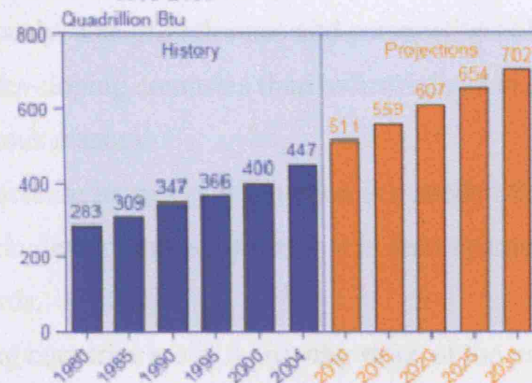
## 2. The global issues of sustainability

### 2.1 world primary energy consumption

According to the Energy Information Administration (EIA) in its International Energy Outlook 2008 report, an increase of 57 % is expected in the world marketed energy consumption from 2004 to 2030 .

At the same time, the total energy demand in the non-OECD (organisation for economic cooperation and development) countries "increases by 95 percent, compared with an increase of 24 percent in OECD countries" (IPS Inter press service, 2008)

**Figure 8. World Marketed Energy Consumption, 1980-2030**



Sources: **History:** Energy Information Administration (EIA), International Energy Annual 2004 (May-July 2006), web site [www.eia.doe.gov/iea](http://www.eia.doe.gov/iea). **Projections:** EIA, System for the Analysis of Global Energy Markets (2007).

**Figure 2: World marketed energy consumption 1980-2030 (IPS Inter press service, 2008)**

The report also estimates a rise from 47.9 percent in 2005 to 58.8 percent in 2030 in the non OCED countries' share for world consumption.

Even the sustained high world oil prices that are anticipated to persist over the long term, (between 113 dollars a barrel and 186 dollars a barrel) are not halting the rate of the world's current energy consumption

The estimated increasing energy demand will partially come from developing countries, with China and other economic dynamos taking the lead. Nearly three-fourths of an expected 2 percent annual increase in the global use of coal will come from Asia alone.

reports also predicts the demand for oil ,topping 113 million barrels a day by 2030, and other liquid fuels growing to nearly one-third more than today's consumption. (IPS – Inter press service, 2008)

## 2.2 rising energy demand in developing countries

Primary energy consumption in the industrial sector grew from 89 EJ in 1971 to 160 EJ in 2004 (Price et al., 2006). Primary energy consumption in developing countries grew at an average annual rate of 4.9% per year over this time period. (Mckane et al, 2008)

As mentioned previously, The growth rates and perspectives of energy consumption are much higher in developing countries than industrialized countries. This discrepancy has various reasons:

First, a substantial increase in energy production is a needed due to the rapidly growing population in developing countries that is accompanied by a demand for higher living standards.

Secondly, developing countries are at a growing stage of the process of industrialization, where the energy intensity is rather high compared to industrialized countries; where in some cases a saturation level has been reached. Thirdly, most of the developing countries lack the knowhow, expertise and skilled labour to plan and maintain energy efficient practices throughout different development sectors.

Also, high-energy consumer products and electrical appliances are becoming more and cheaper and available to the developing countries through growing international open markets.

## 2.3 Fossil fuel depletion

The energy consumed globally for development is directly supported by fossil fuels. Diminishing fossil fuel reserves is one of the primary concerns of governments



around the world, as oil companies estimate that reserves will be exhausted in about 40 years (Peter F. Smith, 2005)

One of the alarming scenarios projected is The Hubbert peak theory, which makes projections of production rates based on previous discovery rates and expected production rates.

According to an estimate by the American petroleum institute, the Hubbert curves predicts that "the production curves of non-renewing resources approximate a bell curve. Thus, when the peak of production is passed, production rates enter an exponential decline". (Wikipedia, oil depletion, 2007)

According to another estimate by the American Petroleum Institute in 1999, assuming total world oil reserves at between 1.4 and 2 trillion barrels and consumption at 80 million barrels per day, the world's oil supply would be depleted between 2062 and 2094.

Lower living standards in developed and developing countries are to be expected if the oil supply continues to decrease and no alternative natural energy sources are being utilized.

Scenarios of the impact of oil shortages go as far as predicting the collapse of the entire international banking system. Political tensions and disputes may arise over access to diminishing oil supplies.

Even with a more reserved scenario that assumes a slower rate of depletion and a smooth transition to alternative energy sources, major economic recessions will occur as a result of higher energy prices, as there was always a close connection in the timing of oil price increases and economic declines in the past.

Increased energy consumption poses even more alarming threats than the collapse of world economies and compromised living standards. The increasing rate of fossil fuel consumption responding to the increasing energy demands could lead to phenomenon's that have irreversible disastrous impact on the environment, such as global warming.

## 2.4 Global warming

Over the past 100 years, the universal average of surface temperature progressively increased by 0.3-0.6c. (Egypt state of the environment report, 2005)

IPCC studies have concluded if the ratio of the increase remains unchanged; the world will soon face a global scale crisis

Scientists were alerted in June 1990 by a graph which appeared in the journal Nature. It was evidence from ice core samples which showed a remarkably close correlation between temperature and concentrations of  $\text{CO}_2$  in the atmosphere from 160 000 years ago until 1989. It also revealed that present concentrations of  $\text{CO}_2$  are higher than any time over that period. (Peter F Smith, 2005)

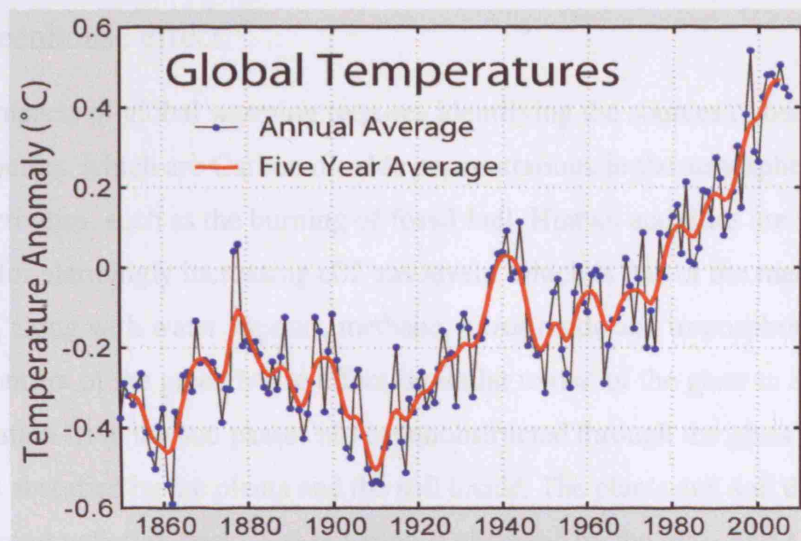


Figure 3: Global temperature fluctuations 1860-2000

(Wikipedia, global warming, temperature changes, 2007)

An increase of Global temperatures by  $0.75\text{ }^{\circ}\text{C}$  ( $1.35\text{ }^{\circ}\text{F}$ ) relative to the period 1860–1900 has been recorded on both land and sea, an increase that was not notably affected by the urban heat island effect, according to the instrumental temperature record.

Land temperatures have increased about twice as fast as ocean temperatures ( $0.25\text{ }^{\circ}\text{C}$  per decade against  $0.13\text{ }^{\circ}\text{C}$  per decade) since 1979.

(Wikipedia, global warming, temperature changes, 2007)

Before 1850, Temperature is believed to have been relatively stable over the one or two thousand years, with possibly regional fluctuations such as the Medieval Warm Period or the Little Ice Age Climate.

The IPCC projects that during the twenty-first century average global surface temperature is likely to rise a further 1.1 to 6.4 °C (2.0 to 11.5 °F). This will result from the future estimated production of greenhouse gas emissions.

Global warming is expected to cause irreversible catastrophic phenomenon's, such as species extinction, extreme climatic conditions such as increased storms and tornados , sea level rise, change in waterfall patterns, changes in agricultural yields, which can cause large scale food shortages, glacier retreat, an increases in the ranges of diseases (Wikipedia, global warming Attributed and expected effects, 2007 )

## 2.5 The greenhouse effect

Facing the impacts of global warming requires identifying the sources of one of its main contributors, which are Carbon dioxide concentrations in the atmosphere caused by human activities, such as the burning of fossil fuel. Human activities are responsible for alarmingly increasing c02 gas levels, which is one of the main green house gases, along with water vapour , methane, nitros oxide and troposphoric ozone. The basic concept of the green house effect is similar to that of the glass in a green house. Radiation from the sun passes almost unobstructed through the glass in a green house and is absorbed by the plants and the soil inside. The plants and soil then re emit the thermal radiation back. The radiation is absorbed by the glass and a percentage of it is re emitted back into the green house by the glass, which acts as a 'radiation blanket' which re-emits some of it back into the green house. The green house thus remains warm. ( Houghton ,1997)

In the same way, 'green house' gases collaborate to form a canopy over the Earth, which causes solar radiation to reflect back into the atmosphere. With the increased temperature, the amount of water vapour in the atmosphere increases in parallel, providing more blanketing and causing even more warming. (Houghton, 2004)

## 2.6 Manmade climate change

International forums and conferences have been held, debating for years whether Global warming is a result of human activities or of a number of natural factors such as the variation in the Earth's axial tilt, The movement of tectonic plates or the resultant formation of volcanic mountains and Volcanic activity (Smith, 2001). The



more the science of climatology advances and rigorous climatic researches and recent analysis are conducted, the less doubt there is that human activity is a significant contributor to global warming. According to the 2007 report released in February by the United Nations Intergovernmental Panel on Climate Change (IPCC), world warming due to human activities is “unequivocal”. (Rosenthal et al, 2007)

Susan Solomon, The co-chair of the IPCC working group that produced the report, stated that “There can be no question that the increase in these greenhouse gases are dominated by human activity“, referring to records from ice cores, going back 10,000 years that demonstrated a dramatic rise in greenhouse gases from the onset of the industrial era.

### 3. Situation in Egypt

Egypt's energy consumption is relatively low, at only 0.57% of the world total, and is projected to increase to 0.75% by 2025.

## CHAPTER.3: SITUATION IN EGYPT

collection global efforts to reduce greenhouse gas emissions, this increase in levels of consumption in Egypt has led to local regional and diverse development needs. Increased urbanization and economic growth in Egypt's major development by 2025, which is expected to be a significant challenge for the country.

### 3.1 Rising energy consumption in Egypt

The energy demand in Egypt has been growing steadily at 5% per annum.

With a growth rate of 5.10%, electricity consumption figures in 2003, consumption increased from 12.45 TWh in 2000 to 15.28 TWh in 2003.

(Badr et al. 2003)

The demand growth rate in 2003 was 22.4% for the electricity sector, 17.4% for gas, and 6.7% for electricity. The growth rate in the electricity sector is 22.4% for the electricity sector, 17.4% for gas, and 6.7% for electricity.

In 2003, the electricity generation capacity was 10,900 MW, increasing to 15,286 MW in 2003, with a growth rate of 4.6%.

Electricity consumption increased from 12.45 TWh in 2000 to 15.28 TWh in 2003, with a growth rate of 5.1%. The electricity sector is the largest consumer of electricity, accounting for 39.1% of the total consumption, followed by the industry representing 37.9%, (Badr et al. 2003).

A study by Egypt's Ministry of Planning and Economic Development is included in the appendix (Appendix 1).

### 3. Situation in Egypt

Even though Egypt's contribution to global warming is relatively minimal, as only for 0.57% of the world's total emissions (Egypt state of the environment report, 2005), Egypt is considered as one of the most vulnerable countries to climatic change impacts. (M. El Raey, Impact of climate change on Egypt). The impacts of global warming in Egypt include drastic effects on health, agriculture, water resources and will cause sea level rise in coastal regions, threatening infra structures as well as natural and cultural heritage. Global warming is a global problem that needs collective global efforts to reduce green house gases emissions. In addition to global warming impacts, The increasing levels of co2 emissions resulting from energy consumption in Egypt has its own local negative consequences on health, agriculture and diverse development sectors. Increasing energy consumption also threatens to obstruct Egypt's future development by depleting the country's non renewable energy resources.

#### 3.1 Rising energy consumption in Egypt

The energy demand in Egypt is rapidly growing, reaching about 2.6 % per annum. With a growth rate of 5.19%, (International Energy Agency, 2003) the energy consumption increased from 32.45 MTOE in 2001/2002 to about 34.75 MTOE in 2002/2003 (Badran et al, 2003)

The demand growth rates in 2003 were 2.7 % for petroleum products, 13 % for gas, and 6.8% for electricity. Electricity is the main energy source for Industrial and agricultural development projects, housing and services.

In 2001/2002, total electricity generation was 14582 MW, increasing to 15286 MW in 2002/2003 with a growth rate of 4.83% .

Electricity consumption increased from 64.86 TWh in 2001/2002 to 68.3 TWh in 2002/2003 with a growth rate of 5.7%. The residential sector is the major consumer of electricity , accounting for 39.1% of the total consumption, then, industry representing 37.8%. (Badran et al, 2003)

A study of Egypt's Main energy resources and renewable energy potential is included in the appendix. (Appendix 1)

### 3.2 Challenge of meeting energy demands for development

The country's primary energy consumption is alarmingly rising, as it has more than tripled for the last two decades. Some projections expect that Egypt will begin importing oil as early as 2010 due to the declining production levels of the oil fields and the current growth rate for oil products. . (Badran et al, 2003)

Egypt's rapid growth in the industrial, commercial, residential and agricultural sectors demands additional supply of generating capacity for electricity. The expected maximum load will reach 33,200 MW by the year 2022, Compared to the actual maximum load of about 15,000 MW(in 2003). An additional expansion of 33,600 mw of new generating facilities is estimated as an expansion to the current installed capacity of 17,700 MW, requiring a financial investment reaching US\$20 billion. . (Badran et al, 2003)

At the same time, about US\$5 billion is required for the related expansion to the grid. Strategies that use more renewable resources of energy must be adopted in the next years to meet the escalating demand, which will increase even more with the blowing up population.

Responding to the increasing demands with the typical supply-oriented approach would accelerate the depletion of the country's resources, flatten export revenues, and have major negative impacts on the environment.

The Ministry of Electricity and Energy has initiated an energy strategy as a base for development for the 21st century to face the increasing energy demands. One of the strategy's targets is to reach 3% of total power produced by 2010 from renewable and clean sources of energy ( Badran et al, 2003)

the following figure shows the contribution of each development sector to the annual energy consumption.:

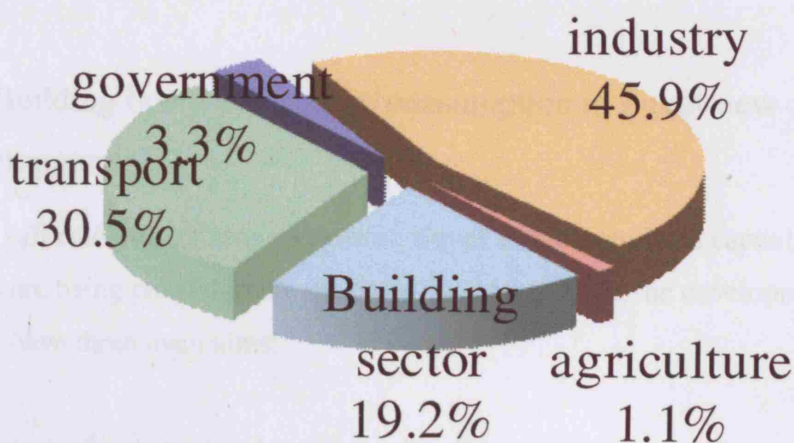


Figure 4: energy consumption from different economic sectors ( Dr. Essam El-Deen Badran et al, 2003)

year	Industry	Transport	Building sector	Agriculture	government	Total
2001/2000	14.91 MTOE	9.90 MTOE	6.23 MTOE	0.34 MTOE	1.07 MTOE	32.45MTOE
2000/1999	14.02 MTOE	9.65 MTOE	6.02 MTOE	0.33 MTOE	0.83 MTOE	30.85 MTOE
Growth	6.4%	2.5%	3.5%	3.2%	29.6%	5.2%
Share	45.9%	30.5%	19.2%	1.1%	3.3%	100%

Table 1: The Egyptian energy consumption of different economic sectors (Badran et al, 2003)

As shown in the table, the building sector accounts for 19.2% of the annual energy consumption. This percentage is expected to substantially increase due to the current increase of investments in the building sector and the newly developed cities developed by the government in the desert that attempt to reduce the congestion of the capital and provide more housing projects for the rapidly increasing population.

The factors contributing to the boom of the building sector will be discussed in the following section, as well as the sector's future direction.

### 3.3 Building boom and energy consumption in Egypt-new cities development

In an effort to pull citizens away from Egypt's over populated capital, Cairo, new cities are being created in the desert by the government, the developments of these cities have three main aims:

- Creation of new civilized centres, achieving community stability and economic prosperity.
- Redistribution of population far from Nile Delta narrow stripe.
- Establishment of new attraction areas outside the existing cities and villages.
- Curbing the urban infringement upon cultivated areas.
- Limiting the spreading of informal settlements phenomenon in Cairo

An in-depth discussion of the need to relocate in the desert is included in the appendix (appendix 2)

These cities are currently witnessing a boom in the construction of factories and mega residential, touristic and industrial projects. The reasons behind this boom includes:

#### 1. Increased entry of foreign investment money to the Egyptian market

Direct Foreign Investment in Egypt had increased from 4 billion US\$ in 2004 to 7 billion US\$ in 2006. (Red sea investors website, October 2007) especially from the gulf countries.

#### 2. Aggressive economic reforms leading to major change in the Egyptian investment legislations.

#### 3. The government's decision to give free hold property to foreign purchasers.

The country's improving economy and regional stability has also encouraged gulf development companies such as Damac, Emar and Diar to heavily invest in real estate projects across Egypt. The final result was a sudden increase in property demand in the Egyptian local market and an overall boom in the construction and building sector.



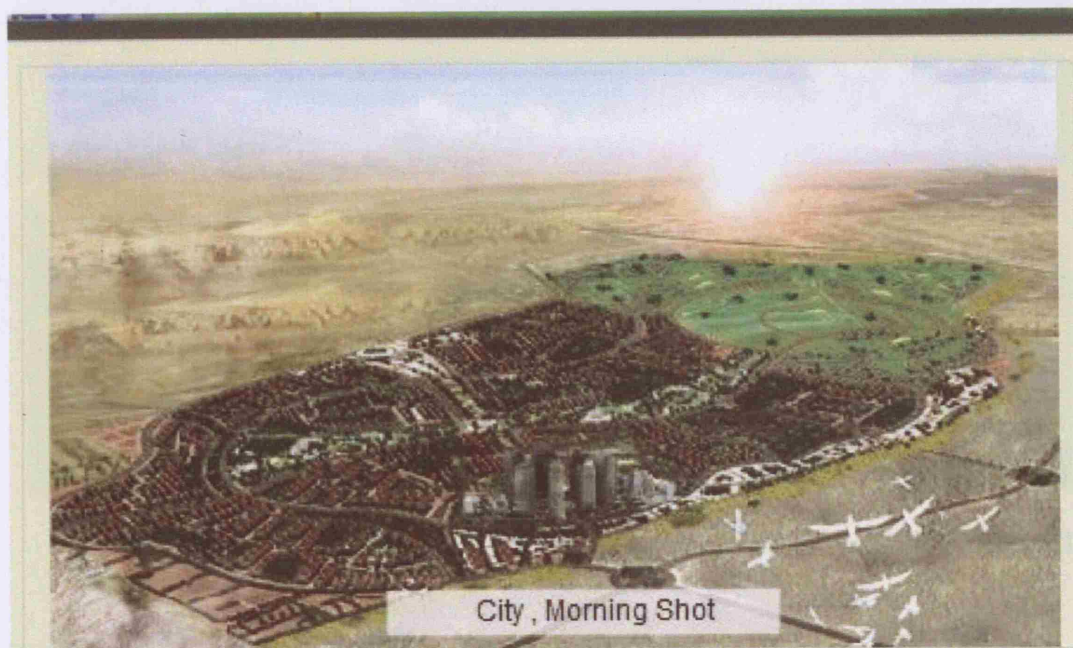


Figure 5 & : 6: renderings of 'madina' city, of one of the mega real estate projects currently being developed in Egypt (source: <http://www.madinaty.com/> )



Figure 7: image of one of the new upscale residential projects currently developed

The development in these cities are considered a great asset for the national economy, but on the other hand, are threatening to further escalate energy consumption, green house gases emissions and negative environmental impacts if an environmentally sensitive and energy efficient approach is not integrated in its planning and implementation phases. The industries, housing and commercial facilities being developed in new cities will result in the overuse of electricity and resources for power generation, producing emissions that add millions of tons of CO<sub>2</sub> to the percentage that is already present in the atmosphere each year.



## CHAPTER.4: ENVIRONMENTAL DESIGN FOR NEW DESERT COMMUNITIES

In order to apply effective environmental design strategies to building new desert communities in Egypt, an understanding of the local climatic conditions have to first be achieved in order to achieve the appropriate architectural strategies to the design. This section of Cairo's climatic conditions and the role of the Egyptian Meteorological authority in Cairo as it relates will be covered in the following section as an example.

### 4.1 Cairo Climate Analysis

The first step in developing an effective environmental design community in the desert is to develop an understanding of the climatic conditions and define a specific zoning range for the future landscape.

#### 4.1.1 Weather analysis

To define the weather conditions of the site, minimum temperatures, data from 1976 to 1999 was analysed to select an optimal year that had the least difference in temperature and moisture from the average.

## 4. Environmental design for new desert communities

Building new urban communities in the desert is a vital opportunity to apply lessons learnt from mistakes of urban development in Cairo development, as it presents the future of Egypt's built environments.

Improving energy efficiency of cities layouts and buildings could reduce carbon emissions as much as focusing on alternative fuels, vehicles, and electricity generation emission reductions.

Better urban design represents an important yet undervalued opportunity. Fortunately, such decisions are well within the reach of local governments, architect and urban planners and can reduce long-term carbon emissions.

Minimizing the energy needs are possible by providing proper and efficient building design and maximizing the use of natural energy sources for heating and especially for cooling.

In addition to reducing CO<sub>2</sub> emissions, sustainable design will also contribute in cutting cost and substantial capital savings as well as provide occupants with a healthier, more comfortable built environment to live in.

In order to apply effective environmental design strategies to building is new desert communities in Egypt, an understanding of its climatic conditions have to first be achieved in order to allocate the appropriate passive strategies to the design. A review of Cairo's climatic condition and the site of the new American university in Cairo campus will be covered in the following section as an example.

### 4.1 Cairo Climate Analysis

The first step in attempting to build new sustainable urban communities in the desert is to develop an understanding of its climatic conditions and define a comfort zone range for its future inhabitants

#### 4.1.1 Weather analysis

To define the weather conditions of the site minimum temperatures, data from 1990 to 1999 was analyzed to select an optimum year that had the least difference in temperature and moisture from the average.

The following figures represent a selection of the weather analysis:

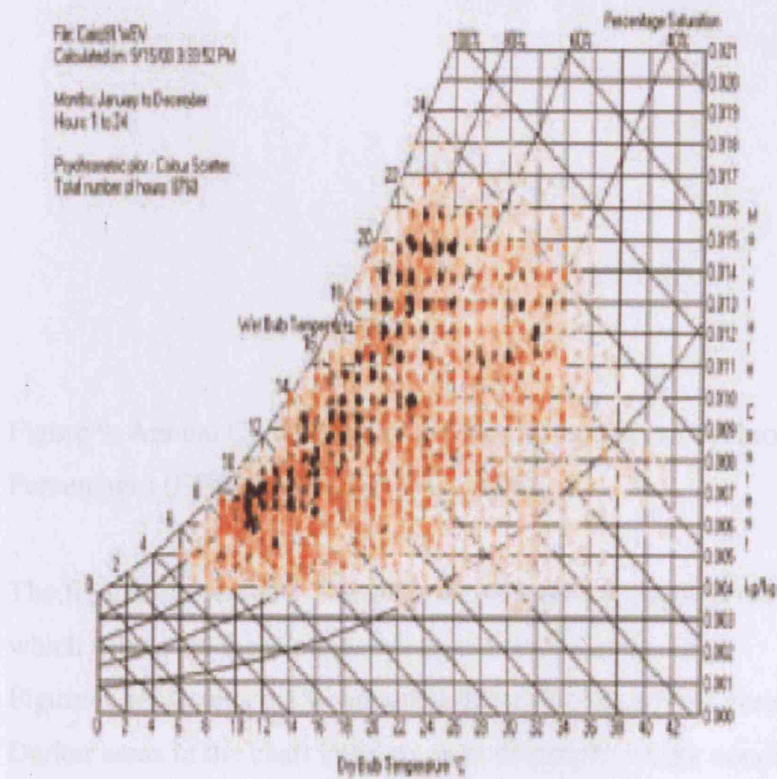


Figure 8: Annual Climate Data for Cairo Plotted on a Psychrometric Chart: Colour Scatter of Data Points (ENSAR GROUP INC.,

200  
0)

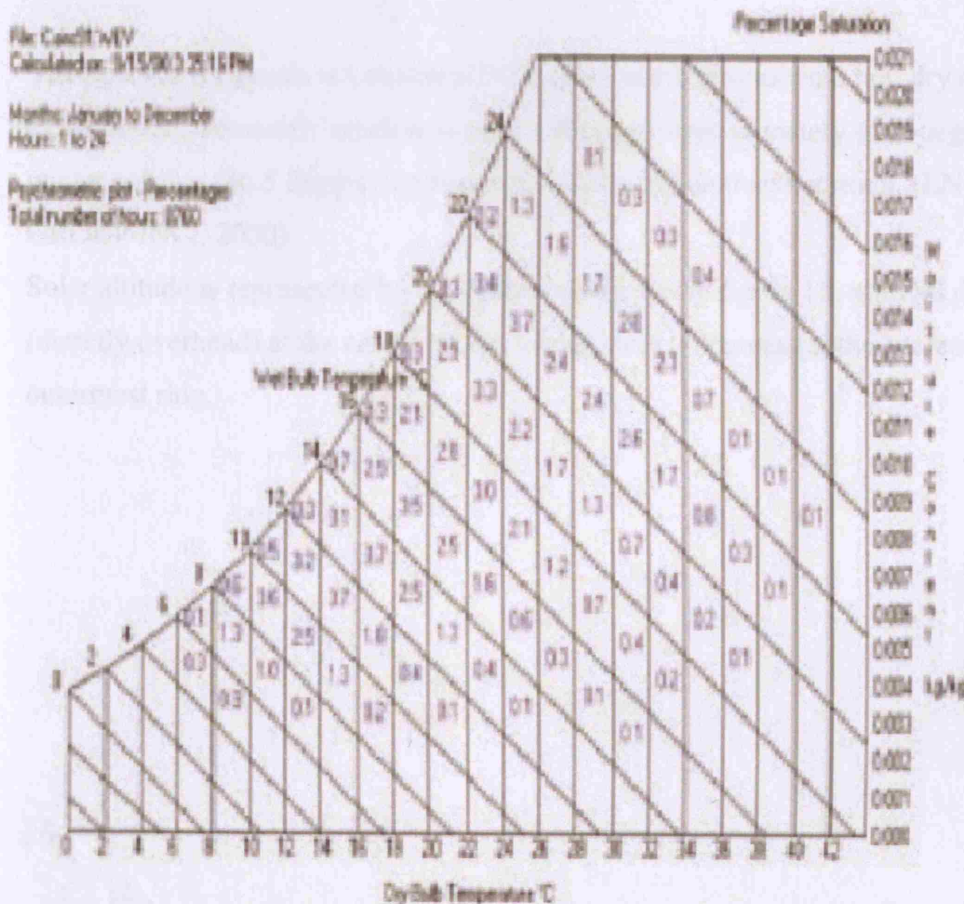


Figure 9: Annual Climate Data for Cairo Plotted on a Psychrometric Chart:  
Percentages (ENSAR GROUP INC., 2000)

The figures above show The 1991 weather data plotted on the psychometric chart, which shows the thermodynamic properties of moist air.

Figure 8 represents the weather conditions for each hour during the year with a spot. Darker areas in the chart indicate more common climate conditions. Figure 9 is a quantified version of Figure 7, showing the percentage of time for which weather conditions occur in each division.

The new AUC campus is Located at 30 degrees north latitude in a hot, dry climate. It experiences a seasonal variation in solar altitude of approximately 47.5 degrees from winter solstice (36.5 degrees) to summer solstice (83 degrees) at noon. (ENSAR GROUP INC., 2000)

Solar altitude is represented by the concentric circles in figure 15, with 90 degrees (directly overhead) at the center of the diagram and 0 degrees (at the horizon) at the outermost ring.



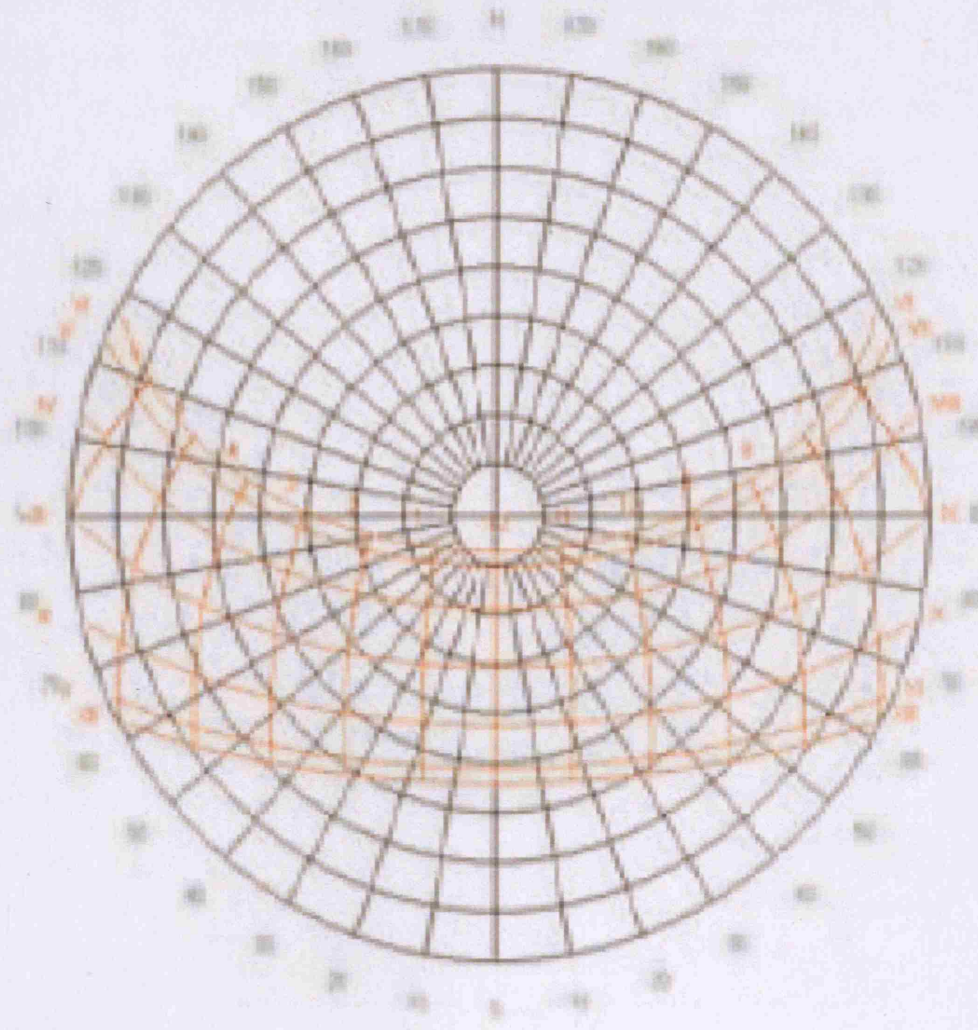


Figure 10: Solar Projection of Sun's Path in Cairo (ENSAR GROUP INC., 2000)

The radial lines indicate azimuth angles, with north at the top of the figure. The red lines indicate the sun's path for each of the seven representative days of the year. The summer sun path lies closest to the center, and the winter sun path lies at the bottom. The lines perpendicular to the sun path lines indicate the time of day, labelled from 6 AM to 6 PM.

Radiation of more than 700 watts per square meter is achieved on horizontal surfaces during much of the day..

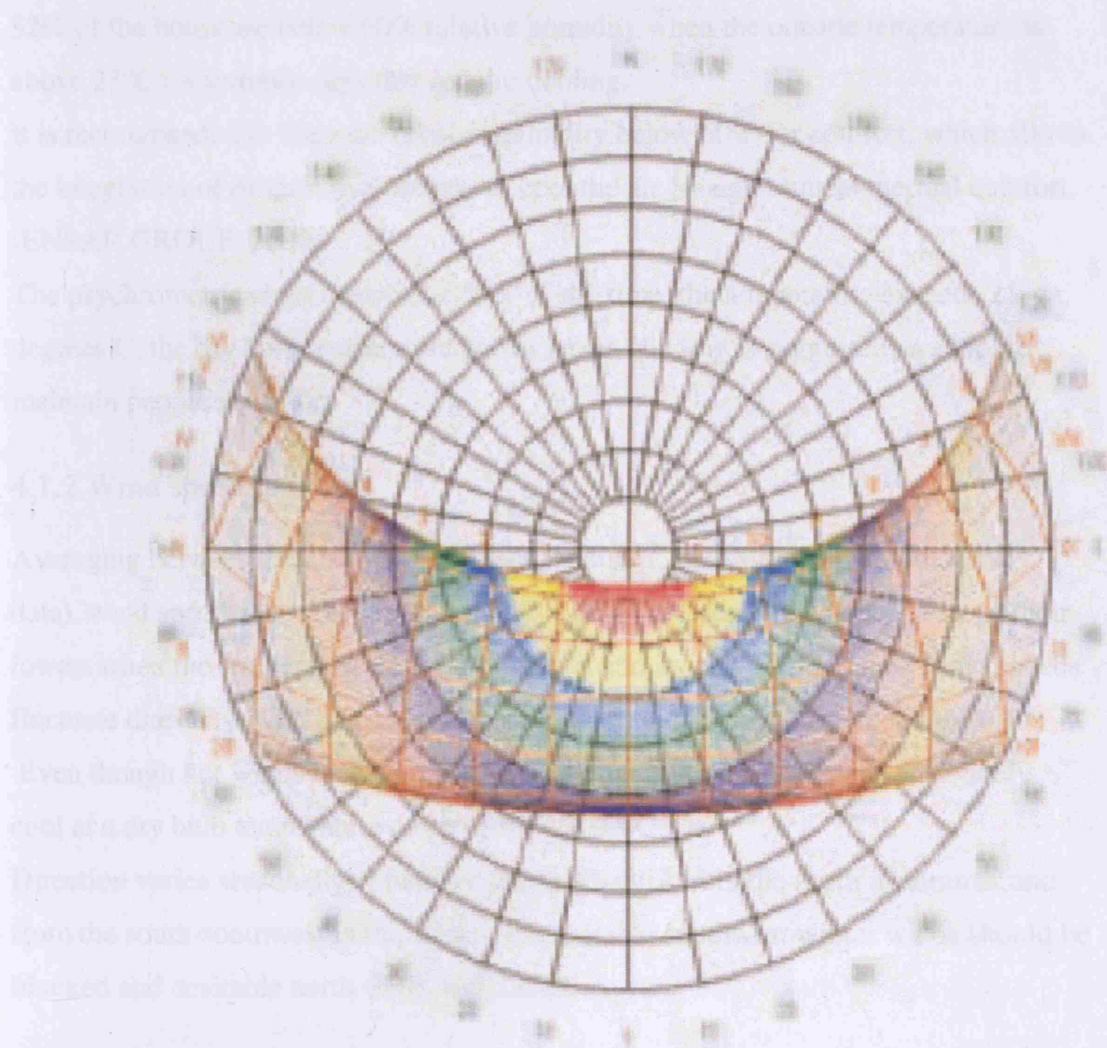


Figure 11: Overlay of Solar Impacts on Cairo's Sun Path (watts per square meter)  
(ENSAR GROUP INC., 2000)

Solar impacts reach their peak at noon in the summer (dark red) and their lowest at dawn and dusk.

The effects of thermal lag, which result in asymmetric impacts, were ignored in these diagrams.

Daytime temperatures in the winter months (December through March) typically range between 13 degrees C and 23 degrees C, suggesting the possibility of the natural ventilation of indoor spaces.

32% of the hours are below 60% relative humidity when the outside temperature is above 23°C on summer days that require cooling.

It is recommended to keep the relative humidity below 60% for comfort, which allows the integration of evaporative cooling to cool the air enough to meet thermal comfort. (ENSAR GROUP, 2000)

The psychrometric chart shows that 55% of the time, the temperature exceeds 21 degrees.C, the dry bulb temperature above which shading is suggested as a tool to maintain people's comfort.

#### 4.1.2 Wind speed in Cairo

Averaging between 2.5 and 3.9 meters per second (Cairo Airport meteorological data), wind speed does not vary greatly throughout the year. Wind speeds are at their lowest when the temperature peaks during July and August. Furthermore, wind speeds fluctuate diurnally, with higher speeds at night when temperatures are lower.

Even though hot winds increase cooling loads of buildings, winds can effectively cool at a dry bulb temperature of up to 35 degrees C.

Direction varies seasonally; winds are predominantly from the north in summer and from the south-southwest in the winter. Undesirable southwest winter winds should be blocked and desirable north winds welcomed.

#### 4.1.3 Defining the comfort zone

In order to define the comfort zone for the university's occupants, 3 factors had to be taken into consideration: measurable, personal and psychological factors.

Examples of measurable factors include radiant surface temperatures, relative humidity, air temperatures and movement.

The psychological factor, which is sometimes neglected, can override the measurable factors. People often feel cooler near a body of water or light coloured surfaces, despite the negligible differences in measurable factors.



The thermal comfort zone may also vary from one country to another.

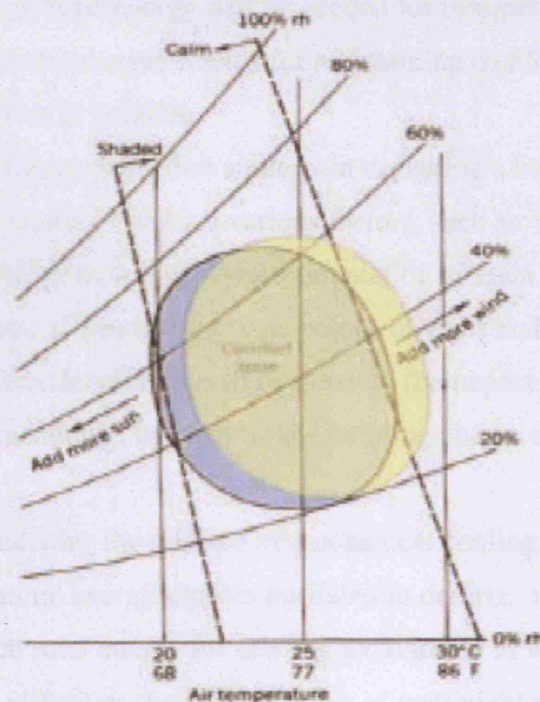


Figure 12: Typical Comfort Zone Defined by Humidity and Temperature (ASHRAE) Egyptians, in general, are more comfortable at higher temperatures than people that live in cooler environments. This is why the comfort zone targeted for the campus may shift slightly to the right, about 3 degrees C (as indicated by the yellow oval) in the diagram. (ENSAR GROUP, INC, 2000)

Acceptable air temperatures for Cairo range between 23 degrees C and 31 degrees C, with relative humidity between 20% and 72%. When temperatures fall below 23 degrees C, solar exposure is desirable; above 31 degrees C, shade is required for comfort.

People's expectations of thermal conditions vary depending on if they are indoors or outdoors, as they tend to tolerate more variation in thermal conditions and are comfortable over a wider range of temperatures when they are outdoors as opposed to indoors, where they expect more stability of the thermal conditions

#### 4.2 Passive design strategies for hot-dry climates

Now that the weather data was analyzed and the comfort zone defined, a study of suitable passive strategies was conducted.



#### 4.2.1 Design for comfort and energy conservation

Although in most cases some energy will be needed for summer cooling and winter heating, reduction of energy requirements for maintaining comfortable indoor conditions in desert areas is possible.

The first stage of the energy reduction strategy in designing a building that minimizes the energy needs for comfort, involves various factors, such as: neighbourhood planning, type of building, buildings layout, orientation of main facades and windows, size location and details of window shading, colour of walls and roof, building material and so on. Consideration should be given to the impact on thermal behaviour of all the previously mentioned features on the building and its energy requirements.

The second stage is reducing the reliance of mechanical cooling and heating by utilizing the use of natural energy sources available in deserts. Potential renewable energy sources include solar energy for heating, availability of water for evaporative cooling, high diurnal variations that allow the use of cool night air for night ventilation, potential of cooled soil, and nocturnal radiant loss. These resources can provide solutions to the necessary energy requirements of the building in an inexpensive and simple manner.

#### 4.2.2 Building's shape in hot-dry climates

It is possible to limit temperature fluctuations throughout the day in hot dry climates by using a compact shape, i.e. keeping the surface area of its external envelope as small as possible, which limits the heat flow into the building.

By keeping the ventilation rate to the minimum required (about 0.5 air changes per hour), minimizing heating of the interior by the hotter external air can also be achieved. (Baruch Givoni, 1997)

By night, a drop in outdoor temperatures occurs, dropping below the internal temperatures, which changes the desired climatic response of the building.

By changing the surface area of the building to spread out at night, the cooling rate of the interior spaces could be speeded up by exposing the building more to the outside air.

This is possible by integrating indented porches equipped with closable insulated shutters along the lines of the external walls. The envelope area is minimized when these shutters are closed and the porches become an integral part of the buildings envelope. The envelope area increases when the shutters open, and the porches area becomes part of the outdoors. These shutters could be in the form of insulated doors. In order to not compromise on daylight and view, Small windows can be added in the shutters when they are closed.

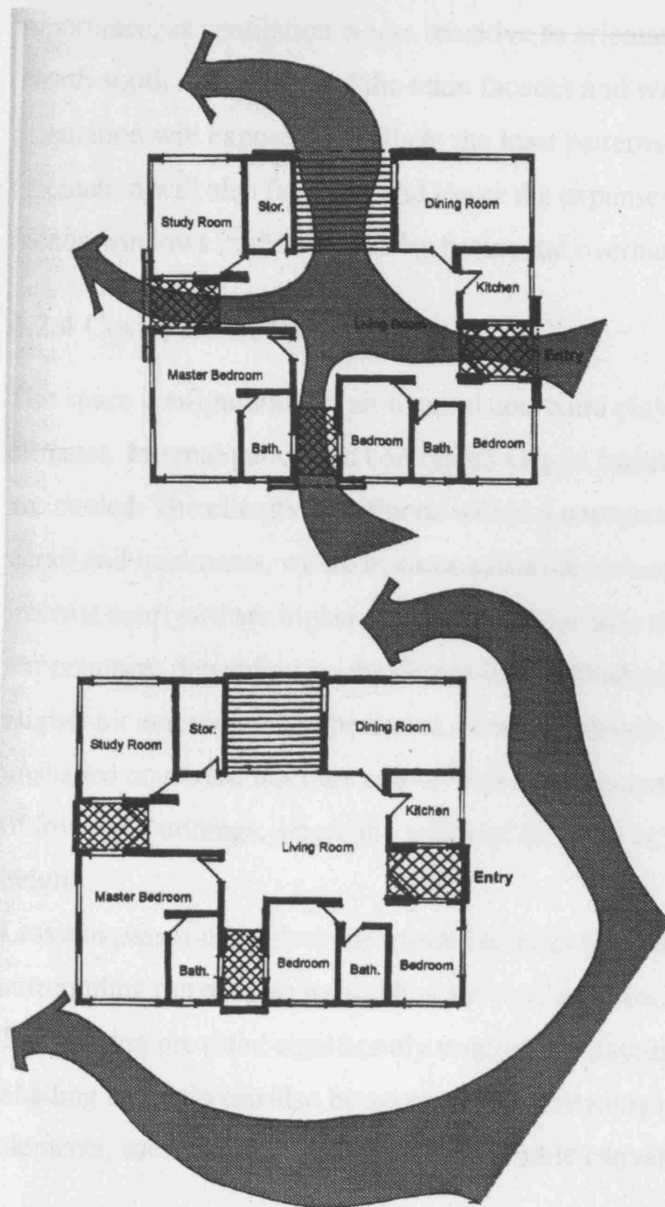


Figure 13: A scheme of a building with indented porches.. Closable by unsulated shutters. (Givoni, 1997)

#### 4.2.3 Building orientation

The way the buildings are positioned and organized on the site has a great influence on their thermal performance and comfort. The optimum orientation on the site could result in big load reductions and positive environmental impacts could be achieved.

The main factor in selecting the optimum orientation for a building in hot-dry regions is minimization of solar impacts on its surfaces in the summer.

Ventilation in the evening hours is secondary in the choice of orientation, despite its importance, as ventilation is less sensitive to orientation.

North-south orientations of the main facades and windows are preferable as the orientation will expose the walls to the least patterns of intense solar radiation. The orientation will also facilitate and lower the expenses of the shading of the southern facade windows in the summer by horizontal overhangs. (Givoni, 1997)

#### 4.2.4 Courtyard house

The space configuration of an internal courtyard plays a special role in hot dry climates. Internal patios and courtyards help in maintaining indoor temperatures that are cooled. The climatic conditions within a courtyard depend greatly on its design detail and treatments, where in some cases the air and radiant temperatures in an internal courtyard are higher, but can be lower than the respective ambient temperatures depending on the design detail of the courtyard.

Higher air and radiant temperatures than the outdoor temperatures could occur if an unshaded courtyard has bare soil or with a hard concrete floor, especially in the case of low-rise buildings, where the width of the patio is large relative to the building height.

Less sun passes through to the ground level as the ratio of the height of the buildings surrounding the patio to its width at the roof level increases.

The shading provided significantly reduces the daytime air and radiant temperatures. Shading the patio can also be accomplished by roofs or balconies or by shading elements, such as trees, canopies or retractable canvas screens at the roof opening.

When shaded courtyards are oriented upwind of the building, it allows ventilation of the building with air cooler than the ambient air.



Figure 14: examples of internal courtyards (source: [http://www.lonelyplanet.com/blogs/travel\\_blog/uploaded\\_images/A-trusty-riad-752382.JPG](http://www.lonelyplanet.com/blogs/travel_blog/uploaded_images/A-trusty-riad-752382.JPG) )

An effective technique is to combine shaded courtyards with evaporative cooling systems, such as fountains, which could lower the courtyards temperature by several degrees below that of the outdoor temperatures.

#### 4.2.5 Evaporative cooling

In hot dry climates, where air doesn't have high moisture content, and air can be cooled by allowing water to evaporate into it.

It works best in dry climates where the average relative humidity at noon in summer does not exceed 40 per cent.

Molecules in a vapour state contain much more energy than the same molecules in a liquid state.

The amount of heat required to change water into vapour is the latent heat of evaporation. This heat is removed from the water, hence 'evaporative cooling' and transferred to the vapour, so evaporative cooling causes the surfaces to cool.

Evaporative cooling can be very effective if it is integrated in the design of external courtyards, providing a number of factors are considered:

- The quantity of air to be cooled, the degree to which it must be cooled
- The amount of water to be used.

As an example, consider the design of a fountain, misting spray, pool, or other water feature in a typical courtyard (11 by 11 by 13 meters). In open courtyards, an air-exchange rate is used rather than an amount of air. Assume an air-exchange rate is 1

air change per hour, a water flow of 1.1 kilograms per hour, and an outdoor temperature of 28 degrees C.

To reduce the temperature to 25 degrees C using evaporative cooling, approximately 1 kilogram of water per hour must be evaporated. At lower air-exchange rates, less water is needed to achieve the same cooling effect. Critical to this strategy is the ability to control the amount of water used. To a lesser extent, control over the water flow and airflow is also needed. (ENSAR GROUP INC., 2000)

#### 4.2.6 Landscaping:

Spending on the energy could be largely reduced and sustained if landscape is integrated to work with the intense summer climate.

Large amounts of solar radiation could be absorbed in the summer by vegetation and the use of natural shade trees, shrubs and vines, which improves the microclimate and helps in keeping the air and ground beneath cool while evapotranspiration can further reduce temperatures.

Grass and other ground cover planting can also influence the microclimate, keeping the ground temperature lower than most hard surfaces as a result of evapotranspiration. This happens due to the shading provided by the grass, which prevents radiation from reaching the ground. Covering external spaces with grass can be quite effective, as the difference between asphalt and lawn is usually as much as 25 degrees F.

(Figures taken from Climatic design, Energy efficient building principles & practices/ Donald Watson and Kenneth Labs)

Wind channelling and circulation of summer breezes can be channelled by careful plantation of trees to provide effective natural ventilation.

Landscaping is an integral part in helping energy-efficient buildings to perform better in the winter and stay cooler in the summer. Using the lay of the land to shelter the building to keep harsh winter winds away and allow summer breezes have been considered. Carefully selecting and strategically planting deciduous trees can provide maximum winter solar gain, as well as effective summer shade. (Ensar Group, 2003)



#### 4.2.7 Passive solar cooling:

##### 4.2.7.1 Roof Ponds

A Storage of water is placed above the roof to act as an extra protecting layer from solar radiation. Water is cooled by night when the insulation is removed and the water exposed, losing significant amounts of heat by radiation to the night sky. Early in the morning, the insulating panels are covering the water in the morning to protect to protect it from the heat of the day and solar radiation.

The ceilings of the adjacent rooms below are cooled by the water that remains relatively cool throughout the day. A cool ceiling is particularly effective in rooms where heat is being generated, as warm air in rooms always rises to the top, a cooled ceiling is particularly effective in bringing the internal temperatures down. To maximise radiant emissions and minimise evaporation, the water is usually contained in black bags or dark coloured containers.

(Square one website, 2007 )

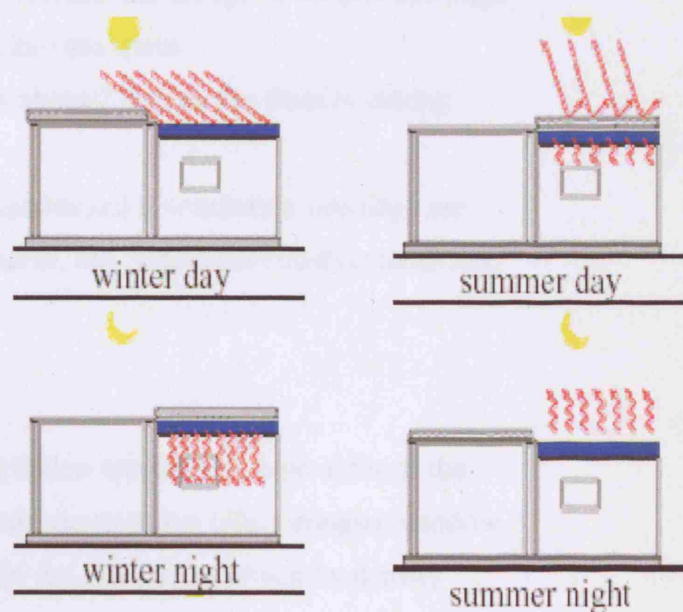


Figure 15: Diagram showing how roof ponds work both in the summer and winter seasons.(source: <http://www.solarmirror.com/fom/fom-serve/bags/skytherm.gif>)

##### 4.2.7.2 Single sided ventilation

Single sided ventilation relies mainly on wind turbulence as a driving force in summer. It provides lower ventilation rates and smaller air penetration distances than other ventilation strategies.

It works through having one opening or more on one side only of the ventilated room. It is closely approximated in many cellular buildings with opening windows on one side and closed internal doors on the other side.

The limiting depth for effective ventilation is about twice the floor to ceiling height. It is also possible to get buoyancy driven exchange through a single opening if the opening is large enough in the vertical dimension. (E.D.E course, nat. Ventilation module handouts, 2007)

#### 4.2.7.3 Double Openings:

The ventilation rate can be enhanced due to the stack effect when multiple ventilation openings are provided at different heights within the facades,

The stack induced flows increase with the vertical separation of the openings and with the inside to outside temperature difference. Another advantage of Double openings is that they increase the fresh air penetration into the space.

The limiting depth for effective ventilation is about 2.5 times the floor to ceiling height.

Height over which the pressure acts can be maximized if ventilation openings are separated from the window itself. (E.D.E course, nat. Ventilation module handouts, 2007)

#### 4.2.7.4 Cross ventilation

Cross ventilation occurs where there are ventilation openings on both sides of the space. Air flows in one side of the building and out the other side through a window or a door. Cross ventilation is usually wind driven, but can be driven by density differences in an attached vertical chimney. Air moving across the zone will pick up heat and pollutants from the occupied space, reducing its temperature and quality.

It must be taken into consideration that there is a limit on the depth of space that can be effectively cross ventilated as, the rule of thumb for the maximum distance between the two sides is five times the floor to ceiling height.

This implies a narrow plan depth for the building. This is usually achieved with a linear built form or wrapping the building around an open courtyard.

By using a narrow plan the spaces gain an added benefit of increasing its potential for natural day lighting.

The main design challenge with such an approach is to organise the form of the building such that there is a significant difference in wind pressure coefficient between the inlet and outlet openings.

This becomes even more difficult for a courtyard based design, because the courtyard and the leeward side of the building will be at similar pressures.

In order to maintain the effect of air flow from cross ventilation, the openings on both sides have to be open and care has to be given with the placement furniture and internal partitions so as to avoid blocking the air flow, especially in summer conditions.

In the occurrence of blockage or the window closing on one side, the ventilation mechanism will change to single sided. (E.D.E course, nat. Ventilation module handouts, 2007)

#### 4.2.7.5 Night ventilation

. Night ventilation works by using the natural diurnal variations in temperature to help ventilation cooling. Because of lower night-time temperature, the inside-outside temperature differences will be greater, enhancing both the stack driven flow rates and the cooling capacity of the outside air.

A reduction in the mean radiant temperature of the space can be achieved by cooling the fabric of the building by night, which enhances the occupant's perception of thermal comfort during the following day.

- When applying Night ventilation, some issues need to be considered:

- The security risk of having windows opens by night. This problem could be solved by using opening limit devices.

- Discomfort could be caused in the following morning if overcooling happens at night due to absence of appropriate controls..

- Good thermal contact (and thus high heat transfer rates) must be ensured between the ventilating air and the thermally massive elements of the building (usually the underside of the floor slab). (E.D.E course, nat. Ventilation module handouts, 2007)

#### 4.2.8 Window insulation:

Windows, which are made up of two components, the glazing and the frame, are weak elements that can cause thermal bridges in a building.

The main component is glass, a thin high thermal conductivity material.

The thermal performance of the glazing can be improved the following:

- Increasing the number of sheets of glass



- Increasing the size of the cavity between the sheets of glass
- Replacing the air cavity with argon gas
- Applying a low emissivity layer to the inner pane of glass

The other element in the window system is the frame. The performance of the frame can be improved by:

- Using low thermal conductivity frame materials
- Creating thermal breaks in the frame

#### 4.2.8.1 Sheets of glass

The number of sheets of glass is inversely proportional to the total u-value, i.e. the more the sheets the less the u-value. The typical u-values for single, double and triple glazing set in a timber frame are 4.8, 2.8 and 2.1 W/m<sup>2</sup>K respectively. Adding more than three sheets of glass is possible but the system loses practicality due to increased cost, weight and dimensions of the unit. The u-values given are for sealed units with a 12mm air gap in between. To avoid condensation forming on the outer sheet of glass, the air in the cavity is dried. The dried air is kept in the unit and an edge seal maintains separation between the panes. This edge seal forms a cold bridge between planes and so heat losses are greatest around the perimeter. The u-value of the double glazed unit excluding frame can be given as a centre of pane value or an overall value taking into account the greater heat loss at the edges. (Nicholls, 2002)

#### 4.2.8.2 Cavity width

The u-value of the window can be reduced by increasing the width of the cavity. The centre pane u-value of double glazing decreases as cavity width increases. The cavity doesn't reduce the u-value any further after 16 mm of width, which is mainly due to the offsetting of the insulating effect of an increased layer of air by increased convective heat transfer, which can take place more easily through a wider gap range. (Nicholls, 2002)

#### 4.2.9 Colours of buildings

The colours of the walls and the roof play a big role on the solar impact on the building and its indoor climate, particularly in desert regions where solar intensity is higher than other regions.

The importance of colour as a controller of the indoor climate is variable because of the different patterns of solar incidence on the roof and on the walls with different orientations,

Because the roof of a building is exposed to direct solar radiation, the colour tones selected are very important.

The maximum surface temperature difference in the summer can reach 40 K between a white roof and a black one.

The extent of effect that colours have on walls depends on their orientation.

The northern wall is the least sensitive, due to its relatively low exposure to direct solar radiation, while eastern and southern walls are very sensitive to their external colour. Careful consideration has to be taken with the southern wall as it receives most radiation in the winter, when heating may be desirable.

When selecting the appropriate colour tones for buildings in the desert, the issue of glare has to be taken into consideration.

because of the light colour of the terrain and the lack of vegetation, occupants of desert buildings may be prone to glare, therefore selecting white colour tones for external surfaces might not always be the most suitable option, as it may strengthen the environmental glare.

Possible solutions could be provided by careful design of some building elements and a selective choice of colours for different parts of the building. (Givoni, 1997)

#### 4.2.10 shading of windows in hot-dry regions:

When ambient temperatures are within or above the comfort zone, any entrance of solar radiation will contribute to discomfort.

Shading design can prevent solar radiation from entering a room through two methods:

- 1) An increase in air mean radiant temperature as a result of radiation absorbed by the room's surfaces.
- 2) Solar radiation falling directly on to an occupant through window openings or sky lights.

Shading design can also decrease glare, a third non thermal factor, which can cause visual discomfort and temporary impairment.

In hot-dry climates, an additional concern is avoiding intense direct radiation and that diffused from the sky, increased by solar radiation reflection and the long wave emission from the surrounding ground (which is usually of relatively light colour and uncovered by vegetation).

Protection from ground reflected and emitted radiation as well as direct sun in hot dry climates can be substantially reduced through adequate shading.

An optimum shading solution is using geometrically selective or movable elements to allow solar radiation to pass by during the winter season to heat up the interior spaces as well as block the sun in the summer. (Givoni, 1997)

When using shading, some factors have to be taken into consideration such as:

- Maintenance of air flow through the building is of great importance during the cooler hours of the day in non air-conditioned buildings. There will also be a need for admitting controlled levels of diffused daylight.
- Requirement for views out of the window, which shading devices could sometimes block.

To carry out the shading function one or more of a number of shading devices can be employed. The devices can be classified into three types.:

- 1- Internal moveable shades
- 2- External shading devices
- 3- Fixed overhangs

(Givoni, 1997)

Each type is discussed in detail in the appendix (Appendix 3)

When selecting between which shading devices to use, it is important to consider issues such as their impact on any natural ventilation strategy, their impact on natural lighting levels and if they are going to contribute to glare and if their use is seasonal or rather on daily basis.

In practice, shading devices are very varied in form and sometimes consists of combinations of the above types. (Square one website, 2007)

#### 4.2.11 Building envelope insulation:

Heat moves naturally from a warm place to a cold place by a combination of 3 heat transfer mechanisms; conduction, convection and radiation. When designing low energy buildings, construction elements that minimize heat transfer from the outside

to the inside and vice versa need to be selected. The thermal transmittance, or the U-value, is a measure of the speed with which heat is lost through one square metre of the element with 1K temperature difference across its faces. The higher the u-value, the greater is the rate of heat loss through a building element. Keeping the heat or the coolth inside the building for as long as possible conserves energy and reduces heating and cooling costs. (Nicholls, 2002)

This can be achieved to a large extent by adding thermal insulation to the building elements, such as external and internal walls, floor slabs and roofs.

Air cavities added between the layers of the wall building elements offer resistance to the movement of heat between the outside and the inside of a building and provide good insulation against conduction. Air spaces resistances are affected by three factors:

- thickness of the air space
- Flow of air in airspace (ventilated or unventilated)
- Lining of air space; normal surfaces or reflective surfaces of low emissivity.

Another effective way of insulating from heat is using thermal insulators that could be added to the inside or outside of the building materials.

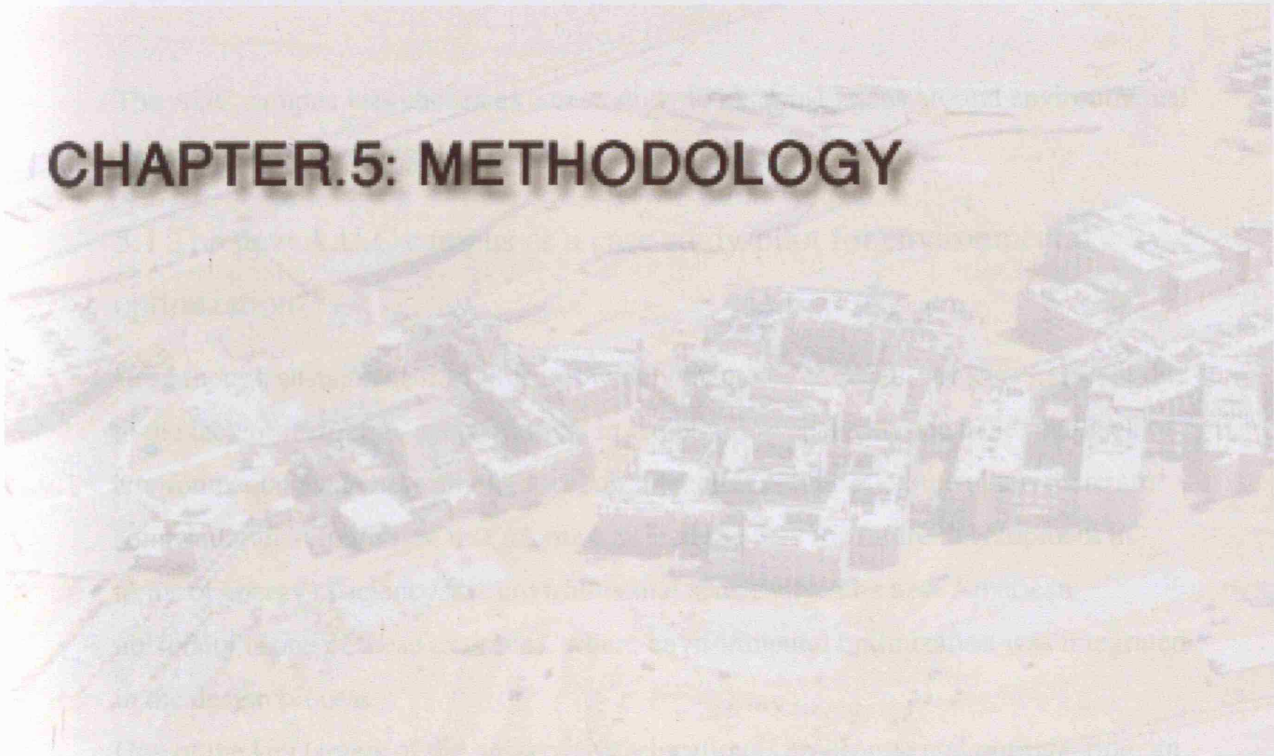
There is a wide variety of materials available but they can be grouped into five categories:

- Rigid preformed materials. Ex: aerated concrete blocks
- Flexible materials. Ex: Fibreglass quilts
- Loose fill materials: Ex: expanded polystyrene granules
- Materials formed on site. Ex: foamed polyurethane
- Reflective materials. Ex: aluminium foil.

(McMullan, 2007)

## 5. Methodology

# CHAPTER.5: METHODOLOGY



major task has been to develop a master plan and a city layout of the new campus. Its significance lies in the fact that it is a new educational institute and its urban and geographical context is very different from the old campus. The new campus is intended to play the role of a catalyst for future sustainable urban development.

In its downtown Cairo setting, the American University in Cairo (AUC) stands out as a modern, high-tech institution due to its location in the city and its design. The AUC is a modern, high-tech institution due to its location in the city and its design. The AUC is a modern, high-tech institution due to its location in the city and its design. The AUC is a modern, high-tech institution due to its location in the city and its design.

## 5.2 Cultural Environmental Optimization Strategies for the New Campus

The environmental optimization strategies for the new campus are based on the following principles:

## 5. Methodology

The AUC campus was chosen as a case study to examine issues around environmental optimisation of dwellings in new desert communities.

### 5.1 The new A.U.C campus as a case study-pilot for environmental optimization

Even though sustainable design is not widely practiced in recent projects in Egypt due to the lack of restricting specifications in the building codes on one hand, and lack of environmental awareness among local architectural practices on the other, there are some individual initiatives that promise to lead the way for future development in terms of energy efficiency and environmental sensitivity. The new American university is one of these examples, where environmental optimization was integrated in the design process.

One of the key targets of the university's relocation is environmental optimization, an aspect that has been taken into account through out every element of the new campus's master planning. Its significant position as a leading higher educational institute and its unique geographical location (center of the new Cairo development, the new campus is intended to play the role of a pilot project for future sustainable urban desert developments.

In its downtown Cairo setting, the American University in Cairo (AUC) didn't function in, or contribute to a clean environment due to its location in the congested down town of Cairo and its rapid expansion that caused scattered previously unplanned building extensions. However, with its relocation to New Cairo on the outskirts of the capital, the AUC aimed to build a campus that meets environmentally friendly architectural and landscaping standards.

### 5.2 General environmental optimization strategies for the new campus

The environmental optimization strategies for the campus consist of 5 core principles:

### 5.2.1 Building orientation:

The building forms were influenced by the different solar impacts on each orientation. During the winter, South elevations have controllable impacts and fewer impacts in the summer. They can provide useful illumination year round. East elevations are quite problematic, as they have considerable thermal radiation and glare. Low sun angles and high thermal loads have to be avoided in west elevations during active times. North elevations have minimal thermal impacts, but require the shading of glazed areas to minimize glare on summer mornings and afternoons. Properly-shaded north windows can effectively daylight interior spaces throughout the year.

. The south orientation receives significantly higher total solar radiation in the winter (5,466 watts per square meter) than in the summer (697 watts per square meter). This is an ideal situation, with natural heating in the winter and cooling in the summer. The southwest orientation receives triple the amount of summer radiation, which can reach 2,068 watts per square meter, triple that of the south orientation. This occurs mainly in the afternoon, with a peak between 2 PM and 5 PM when ambient air temperatures are high. There is a comparable reduction in winter gains. Seasonal impacts on the west orientation are the most extreme. The summer-winter heat gain balance is reversed (1,671 watts per square meter in winter, 2,796 watts per square meter in summer), working against climatic design. This orientation should be avoided and north/south orientations encouraged. (ENSAR GROUP INC., 2000)

### 5.2.2 Building Massing

An outcome of tradition & land use efficiency, compact buildings can contribute to reducing energy load and optimizing comfort. Proper sizes and proportions of interior and exterior spaces improve the effectiveness of passive solar heating and day lighting and greatly reduce energy consumption and negative environmental impacts.

Applications of massing in the new campus include:

- Aggregating buildings to minimize footprint.
- Designing room depths to be less than 2.5 times the window height to receive adequate light and air. (ENSAR GROUP INC., 2000)
- The Use of sun angles and sky view in determining courtyard proportions to provide adequate light and shade.

- Appropriate sizing of courtyards for solar exposure. A larger number of small courtyards were designed throughout the buildings on the campus to assist in accomplishing massing. Courtyards were adequately sized for solar exposure. (ENSAR GROUP INC., 2000)

#### 5.2.4 Porosity

The mass of the built up fabric has been recessed in order to create extra faces and voids. For example, shaded outdoor zones within the building and additional interaction of indoor areas with the outdoor etc. By creating arcades and shaded pathways that serve as transitional spaces between the indoor and outdoor spaces, load reduction could be achieved for the internal spaces in addition to providing shaded outdoor connections between buildings.



Figure 16: example of recessing building mass to achieve porosity

#### 5.2.5 Shading Analysis

An extensive study was conducted to identify walls that are shaded most of the year, as well as the ones that are affected by solar radiation.

Areas that would need shading for the windows were also defined by the analysis.

The outcome of this analysis is a prototypical table in which all facades of the buildings have been investigated by the effect of solar radiation. Specific guidelines, principles and procedures have been outlined for the architects to be applied on all the



buildings on the campus. below is an example of an analysis conducted for the humanities and social sciences building: (ENSAR GROUP INC., 2000)

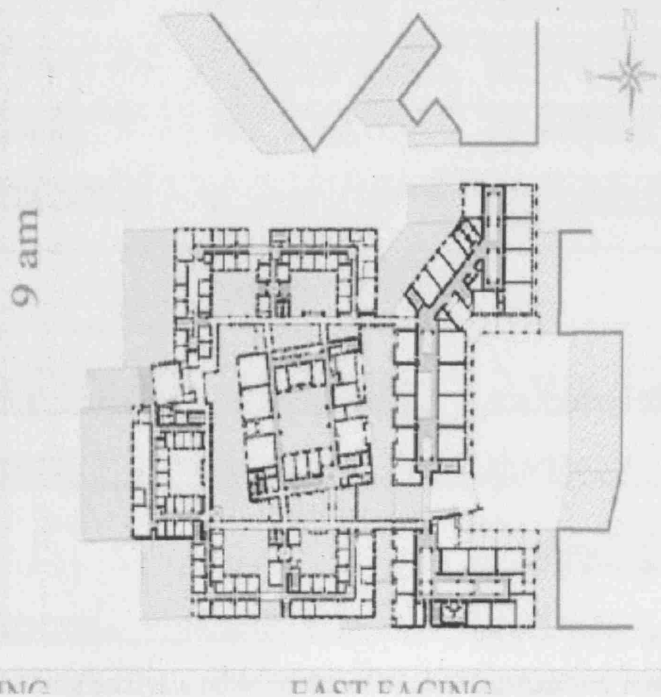


Figure 17: floor plan of the school of humanities and social sciences building (ENSAR GROUP, INC, 2000)

### 3.2.6 The Thermal Unit Concept

#### Description

The thermal unit concept is based on the idea of a building as a single unit that can be designed to respond to the climate and the needs of its occupants. This concept is based on the idea of a building as a single unit that can be designed to respond to the climate and the needs of its occupants. This concept is based on the idea of a building as a single unit that can be designed to respond to the climate and the needs of its occupants.

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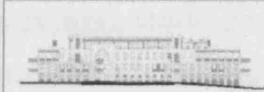

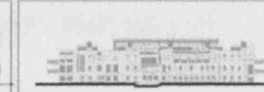

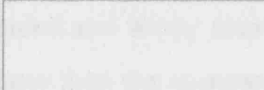


E.O. DESIGN GUIDELINES	NORTH FACING ELEVATION	EAST FACING ELEVATION	SOUTH FACING ELEVATION	WEST FACING ELEVATION
	1- PROVIDE OPTIMUM % OF OPENINGS FOR NORTH FACADE BASED ON EO ANALYSIS (Usually 30-40% openings /solid area)	1- PROVIDE OPTIMUM % OF OPENINGS FOR EAST FACADE BASED ON EO ANALYSIS (Usually 70-80% openings /solid area)	1- PROVIDE OPTIMUM % OF OPENINGS FOR SOUTH FACADE BASED ON EO ANALYSIS (Usually 20-30% openings /solid area)	1- PROVIDE OPTIMUM % OF OPENINGS FOR WEST FACADE BASED ON EO ANALYSIS (Usually 10-20% openings /solid area)
	2- NO NEED FOR SHADING DEVICES UNLESS NEEDED FOR ARCHITECTURAL PURPOSES	2- PROVIDE SHADING DEVICES FOR EAST FACING ELEVATIONS THROUGH HORIZONTAL AND VERTICAL ELEMENTS ACCORDING TO DESIGN GUIDELINES	2- PROVIDE SHADING DEVICES FOR SOUTH FACING ELEVATIONS BASICALLY THROUGH HORIZONTAL ELEMENTS	2- PROVIDE SHADING DEVICES FOR WEST FACING ELEVATIONS THROUGH HORIZONTAL AND VERTICAL ELEMENTS
	3- NO NEED FOR ROTATION OF WINDOWS TO OTHER ORIENTATIONS	3- ROTATION OF WINDOWS TOWARDS NORTH DIRECTION IS APPLICABLE	3- PROJECTION OF UPPER FLOORS IN AREAS FACING SOUTH IS APPLICABLE	3- ROTATION OF WINDOWS TOWARDS NORTH DIRECTION IS APPLICABLE
	4- OUTLINE THE EFFECT OF NORTH FACING ADJACENT BUILDINGS ON DAYLIGHTING	4- NARROW VERTICAL SHAPED WINDOWS ARE PREFERRED THAN WIDE ONES	4- OUTLINE AREAS WHICH ARE SHADED BY OTHER FACING OR SIDE WALLS AND ELIMINATE SHADING DEVICES	4- NARROW VERTICAL SHAPED WINDOWS ARE PREFERRED THAN WIDE ONES
		5- OUTLINE AREAS WHICH ARE SHADED BY OTHER FACING OR SIDE WALLS AND ELIMINATE SHADING DEVICES		5- OUTLINE AREAS WHICH ARE SHADED BY OTHER FACING OR SIDE WALLS AND ELIMINATE SHADING DEVICES
				
	NORTH FACING WALL WITH NO SURROUNDING SHADING SURFACES	EAST FACING WALL WITH NO SURROUNDING SHADING SURFACES	SOUTH FACING WALL WITH NO SURROUNDING SHADING SURFACES	WEST FACING WALL WITH NO SURROUNDING SHADING SURFACES
				
	NORTH FACING WALL AFFECTED BY A SIDE WALL / WALLS OF A FACING SURFACE	EAST FACING WALL AFFECTED BY A SIDE WALL / WALLS OF A FACING SURFACE	SOUTH FACING WALL AFFECTED BY A SIDE WALL / WALLS OF A FACING SURFACE	WEST FACING WALL AFFECTED BY A SIDE WALL / WALLS OF A FACING SURFACE

Table 2: Shading analysis table of the school of humanities and social sciences building (ENSAR GROUP, INC, 2000)

Based on the conclusions of this analysis, the shading devices have been modified on the basis of the recommendations made.

### 5.2.6 The Thermal Unit Concept

#### Description

The thermal unit concept is based on the arrangement of spaces and the influence on their patterns of thermal interactions to modify the internal climate and provide thermal comfort. This strategy has been used throughout time in the desert environment and can serve as an effect technique in optimizing thermal comfort without the use of mechanical systems.

The thermal unit consists of three main elements: A high-pressure or cool element (pit or container), a low-pressure or hot element (field), and a connector that allows air movement (tunnel).

The thermal units are not restricted by a certain size or scale; units occur at several scales simultaneously and are nested with smaller thermal units located within larger ones.

The container, the high pressure element, consists of an enclosed volume that holds cool air. Cool air is generated by evaporative cooling, shading and night sky radiation. Containers in the campus will be comfortable in hot weather (March-November), but too cool in cold weather (December February).

Large containers are called basins and small ones pits.

The field, the low pressure element, works by heating and increasing the buoyancy of the contained as air solar radiation heats surfaces.

The decreased air density will result in an area of low pressure.

Fields can contain both shaded and sunny areas, but will generally be more comfortable during the winter than the summer. Tunnels connect containers and fields. They are basically a linking channel that allow air to flow from one element to the other and do not generate either cool or warm air themselves. The air flow is determined by the proportions of and mechanisms in a tunnel. Tunnels acting as occupied spaces will be more comfortable in the summer than winter. Examples of tunnels in the campus include corridors and arcades with wind towers to assist airflow.(ENSAR GROUP INC., 2000)

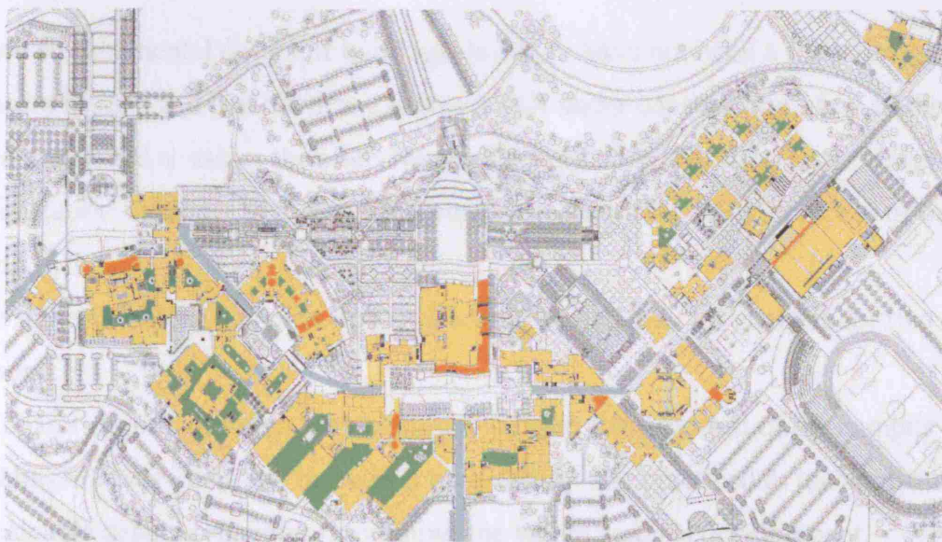


Figure 18: master plan of campus show potential areas for containers



### 5.2.7 Landscaping

Landscaping in the campus is provided as both a measure of environmental optimization, and to create contemplation, relaxation through the extended views of green and open space from windows.

Optimum conditions for cool air reservoirs could be provided by spaces with full and high tree canopies inspired by old, traditional hot climate gardens.

Cooler air is moves from the gardens into the campus core, which consists of hot and open spaces. Air movement corridors should also be fully canopied in order to insure the preservation of thermal convection into the core, Air movement corridors should be fully canopied and shaded. Roof gardens improve the surrounding microclimate by decreasing the heat island effect and stabilizing indoor temperatures. They require only 7-10 centimetres of soil, need little maintenance and can be easily incorporated into building design.

Some guidelines for landscaping include:

- Orient fenestration on the outside of the core campus to specific landscape areas, Preferably to heavily-landscaped areas associated with campus entrances.
- Develop a diverse planting scheme based on vertical and horizontal relationships to water availability and exposure.

. (ENSAR GROUP, INC, 2000)

### 5.3 Methodology:

Since environmental design of buildings in Egypt have not been a main design concern before, and that the new campus is still under construction, few studies have been conducted to assess the effectiveness and applicability of the environmental optimization strategies that were integrated throughout the design process of the campus.

The student housing complex was selected as a case study for analysis for two reasons:

- 1- It has a slightly different architectural character from the rest of the campus buildings. It was important to asses if consistency was practiced in the application of sustainable design principles throughout the whole campus development.
- 2- It presents a prototype for the majority of building types for the future urban desert development, which is dominated by housing projects.

This study attempts to answer the following questions:

- 1- Were the environmental design strategies applied equally throughout all of the campuses parcels and buildings?
- 2- How effective were the selected strategies in reducing potential energy consumption and providing optimum human comfort conditions for the buildings occupants?
- 3- Are there any possible modifications or improvements to the current design that would enhance its energy performance?

The research attempts to answer these questions through analysing the current architectural and construction features of an existing housing unit and examine the impact of different passive design measures in achieving thermal comfort throughout the year. The analysis will be carried out using Thermal Analysis software TAS from EDSL. TAS is a building simulation model allowing the construction of a virtual model of a building and to test its thermal performance under different assumptions and climatic conditions.

The 4 main analysis results sections are :

- setting up the base case,
- Testing different versions of the base case.

Many different options are simulated and each option is explained in turn and the overall results are discussed in chapter 9

- Integrating the thermal unit concept, landscaping and evaporative cooling.
- The last section examines the integration of renewable energy into the site.

After the results is an extensive discussion section examining the results for each passive design measure in detail is conducted.



## 5.4 Student housing parcel description:

### 5.4.1 General description

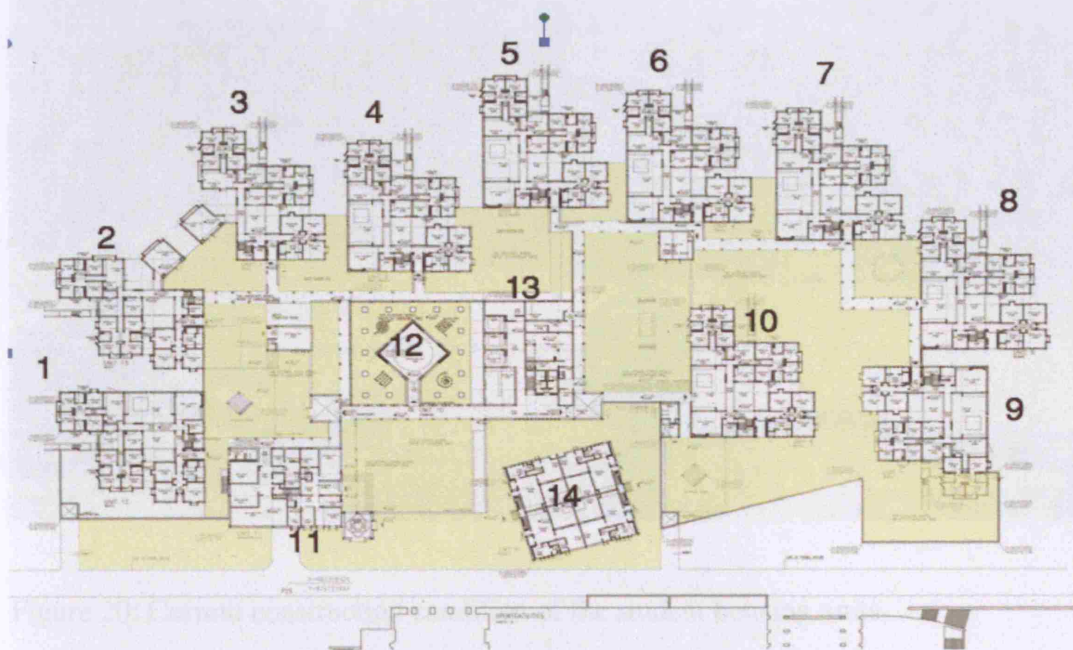


Figure 19: ground floor plan of the student housing parcel (source: Student housing parcel construction drawings)

The ground floor plan above presents the Students housing parcel.

The housing facility parcel consists of 14 buildings forming a cluster around a series of connected courtyards.

Building units 1-10 are student housing buildings, while building 11 is the student housing administration building, building 12 is the recreational activities building, building 13 is the computer lab and lastly building 14 is the faculty housing unit. The student housing units are 5 meters apart and form a cluster around a series of connected courtyards and buildings 11, 12, 13 and 14.

The ground floor starts 1 meter above the plaza level.



Figure 20: Current construction condition of the student housing units

The student housing complex is erected with the same wall and roof built-ups as all the other elements of the campus making it benefit from an advantageous high level of insulation. Since the occupation will be mostly limited to evening and night time, there should be no permanently running air conditioning system but only small units within the individual room to be controlled by the user him/herself.

In the overall design windows are kept to a very small percentage of the building envelope and some of them are located with corresponding fixed external shading elements. Next to the shading fixed windows, small operable windows are envisioned in the form of frameless toughened single glass openings. The design intention was that if the openings are equipped with proper shading devices, then the reduced performance of single glazing can be acceptable. The influence of the various installed shading devices on openings will be examined during the study.



The courtyards amongst the buildings have been connected and provided with a passageway to the outside to allow an undisturbed flow of wind driven air around the buildings and to avoid contained courtyards with trapped hot air. The courtyard Temperatures is another factor that will be later examined in the study.



Figure 21 & 22: series of shaded outdoor corridors connecting housing units

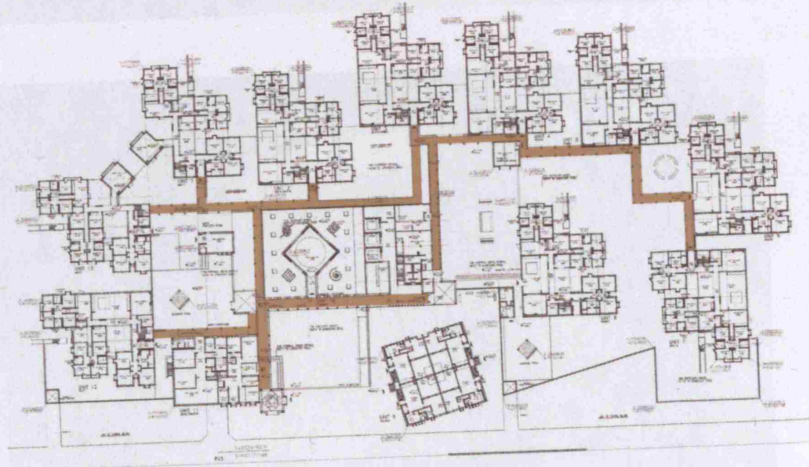


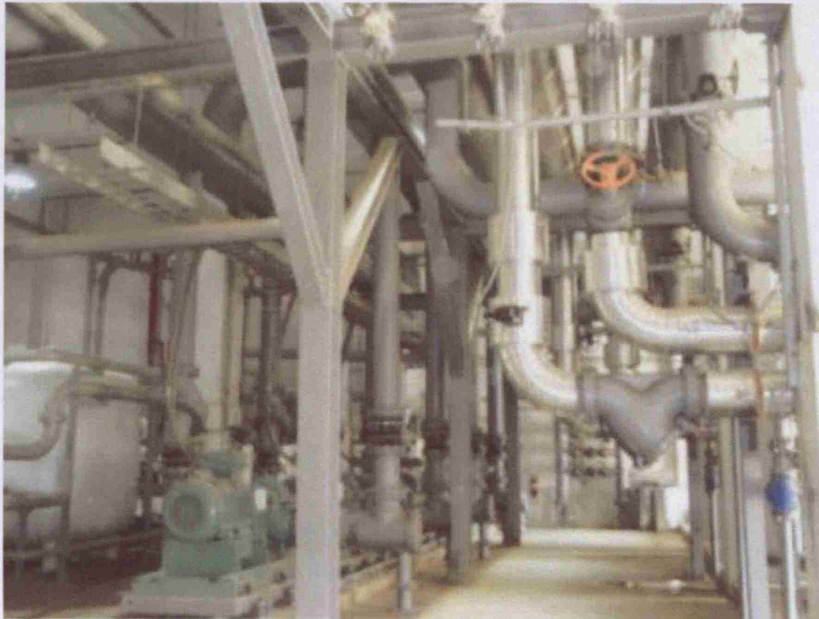
Figure 23: plaza level plan showing series of shaded outdoor corridors connecting housing units

#### 5.4.2 Air conditioning of units

In terms of heating and cooling the rooms of the student housing are conditioned in a similar way as one would treat a hotel room. Individual fan coil units are installed in each room to provide cooling in the summer and heating in the winter. The fan coil



units are supplied with hot and cold water depending on the season through a network of supply and return water pipes that are connected to the main campus chillers and boilers. Energy consumption of the mechanical air conditioning is reduced in the respect that small fan coil type units can produce cooling power locally, on demand, very quickly and only when it is actually needed.



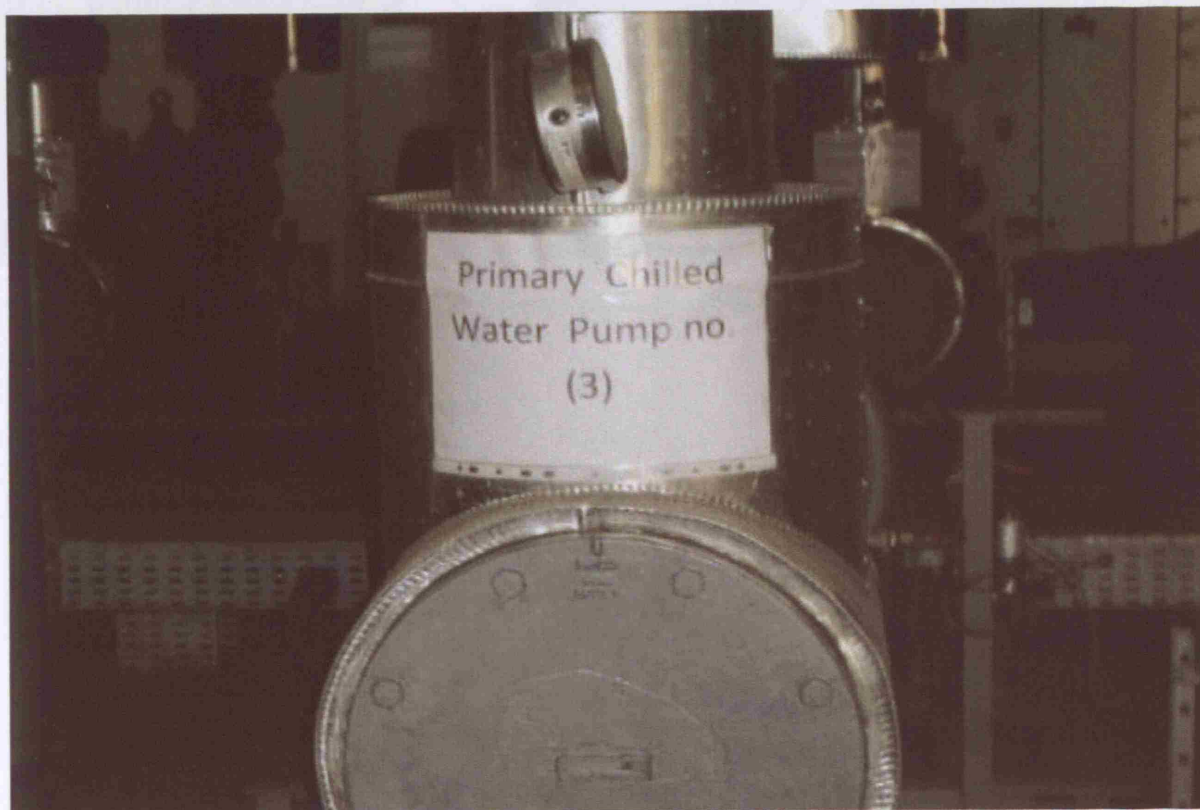


Figure 24, 25, 26 & 27: boilers and chillers inside the main utility building

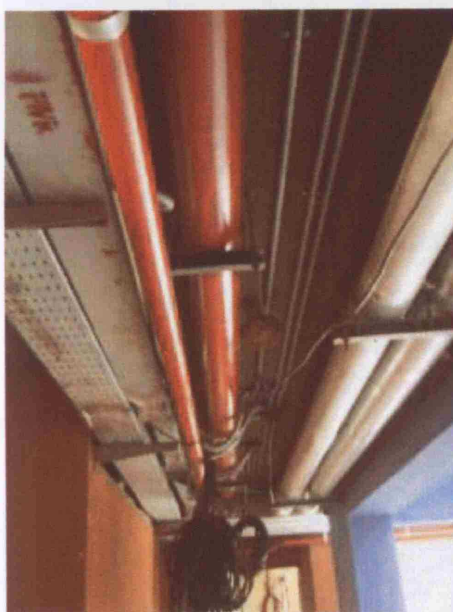


Figure 28 & 29: supply and return water pipes inside the housing unit

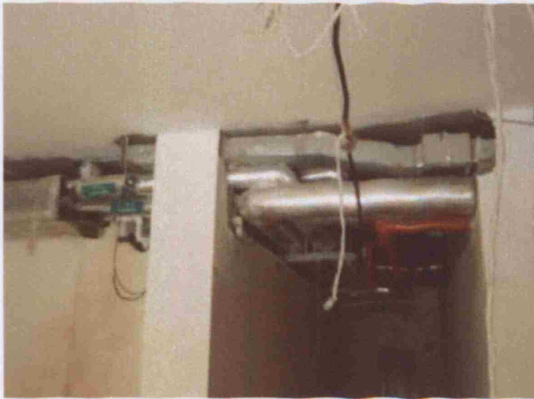


Figure 30 & 31 network of supply and return pipes feeding fan coil units in different rooms:

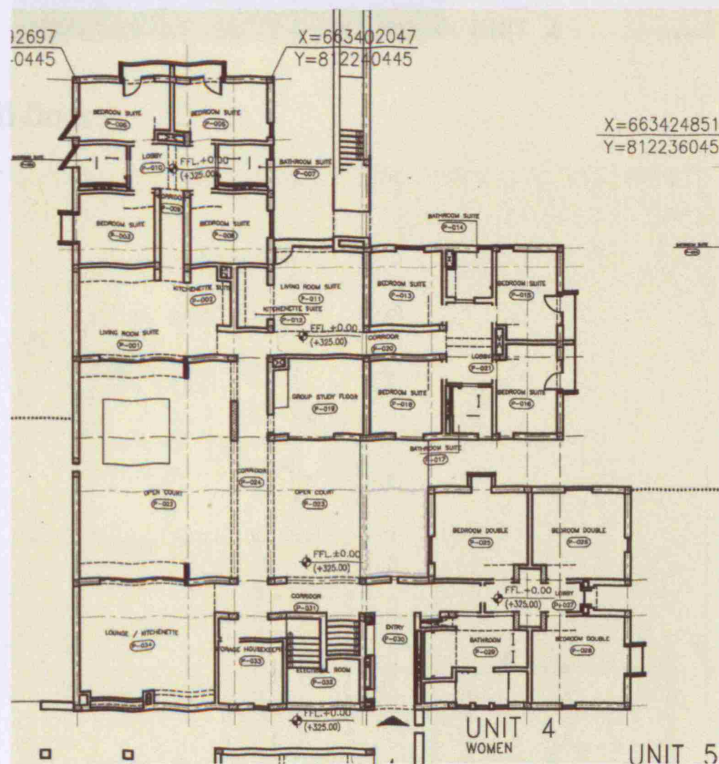
## 5.5 Typical prototype

The typical prototype consists of 3 floors. Each floor consists of a series of bedrooms with their associated living room, study room and kitchen.

### 5.5.1 Floor plans

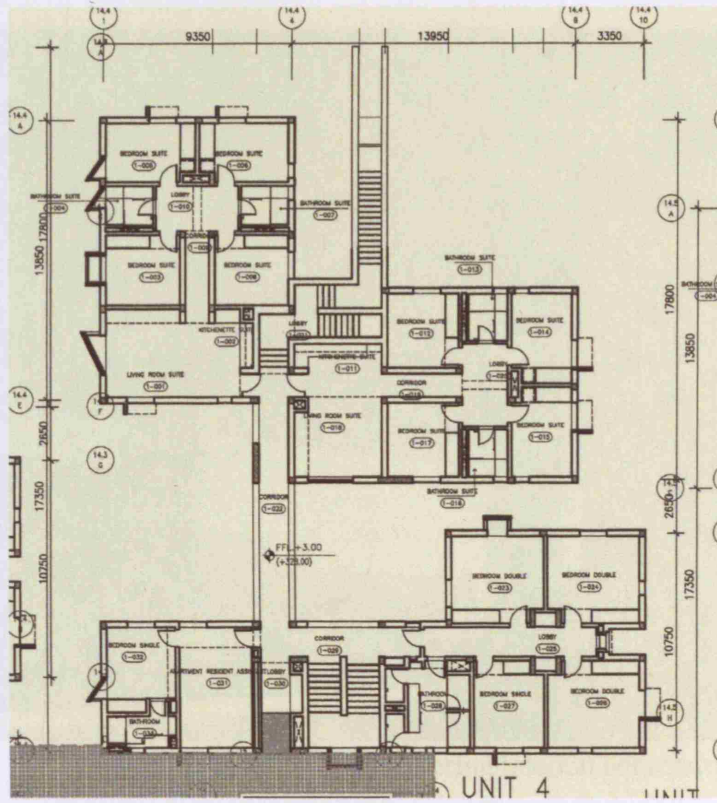
The figures below show the floor layout of each floor:

Ground floor:

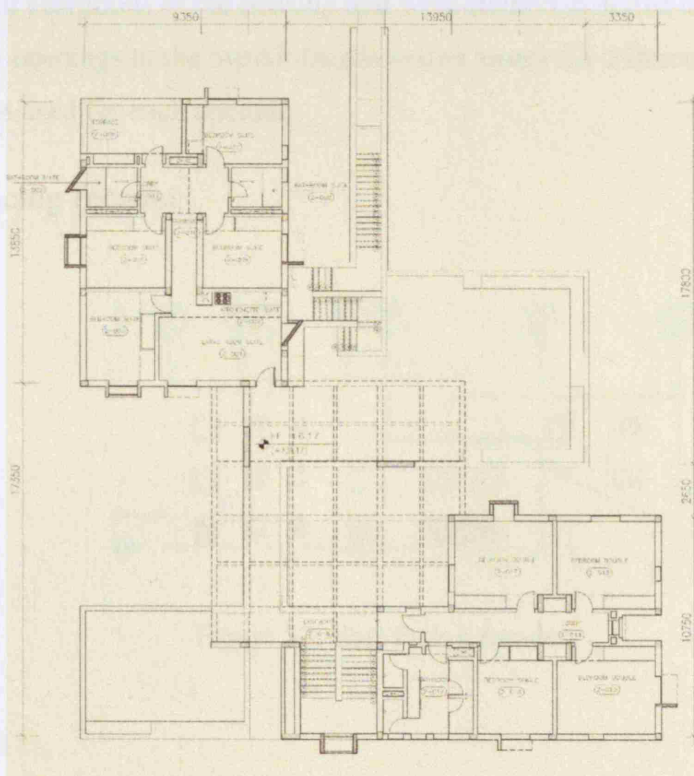




First floor:



Second floor:



The building is wrapped around 2 courtyards. The first is unshaded and the second is shaded by a concrete shading slab on the 3<sup>rd</sup> floor.



Figure.32: Shading slab covering internal courtyard

### 5.5.2 Façade treatments

The four elevations of the housing unit were studied to define the percentage of window openings to the overall facade and to assess the different types of shading elements used for each opening

East facing facade:

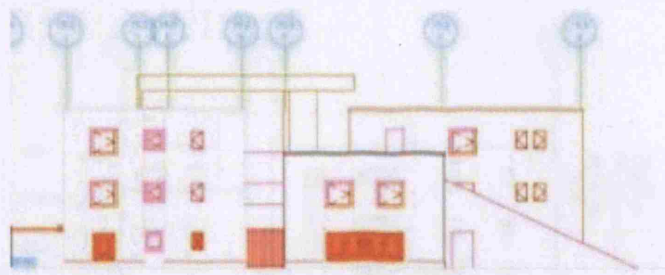


Figure 33: East facing facade

The window treatments for the east elevation are varied, ranging from of extruded frames with mashrabia's (wooden screens) on the ground floor, to Upper horizontal and south facing vertical louvers and unshaded windows on the first and second floors.

Surface area of elevation: 167 m<sup>2</sup>

Total area of windows: 17.33 m<sup>2</sup>

The windows account for approximately 10 % of the facade.

#### North facing façade:

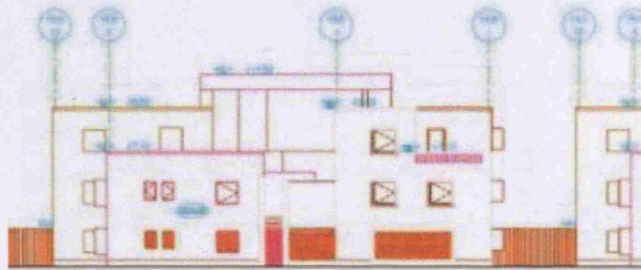


Figure 34: North facing facade

The north façade has mashrabias on the ground floor windows and Upper horizontal and west facing vertical louvers and unshaded windows on the first and second floors.

Surface area of elevation: 178m

Total area of windows: 20.72

The windows account for approximately 11 % of the facade.

#### South facing façade:

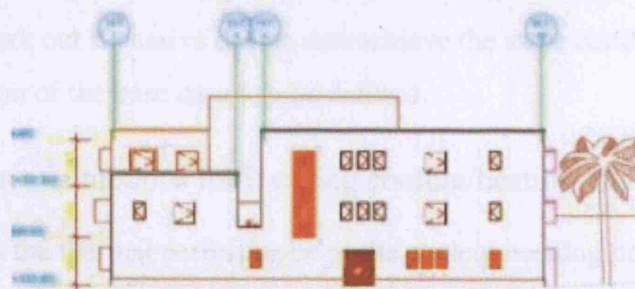


Figure 35: South facing facade



The narrow small windows are on the first and second floors are unprotected, while the three 1.35 x 1.35 windows have horizontal and east facing vertical fins.

The stair case window is extruded and has a wooden mashrabia. All of the ground floor windows are protected with mashrabias.

Surface area of elevation: 235 m

Total area of windows: 26.95

The windows account for approximately 10 % of the facade.

### West facing elevation:

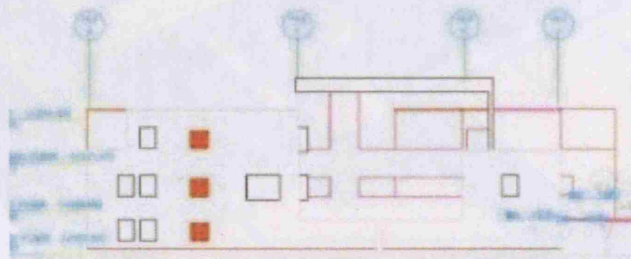


Figure 36: West facing facade

The windows on the west facing facade consist of either extruded frame types or angled extruded windows facing south or north

Surface area of elevation: 189 m<sup>2</sup>

Total area of windows: 10.08 m<sup>2</sup>

The windows account for approximately 5 % of the facade.

## 5.6 Results

Firstly the base heating and cooling loads for the existing situation need to be determined to work out if passive design can achieve the same conditions. After this the passive version of the base case can be defined.

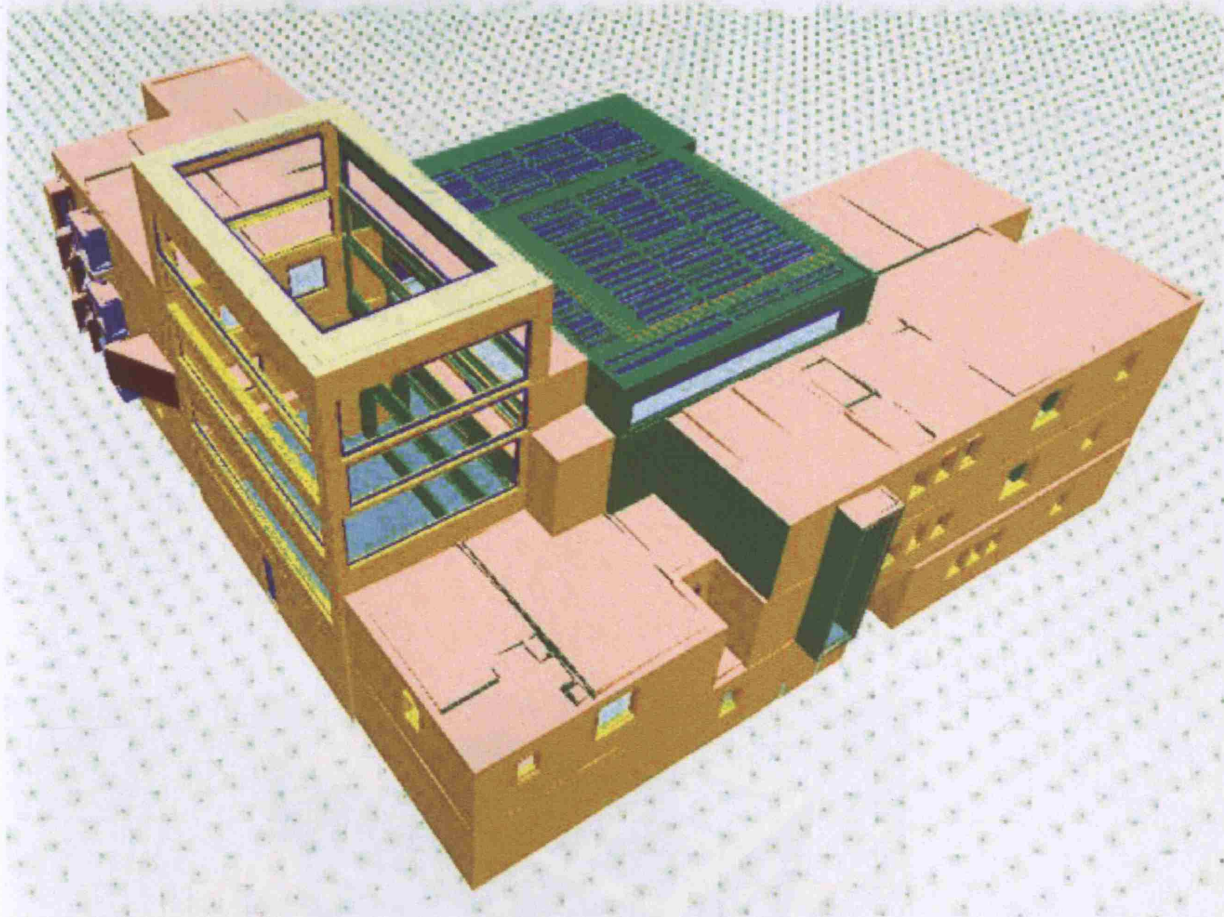
### 5.6.1 Simulation assumptions for Existing cooling/heating loads calculations

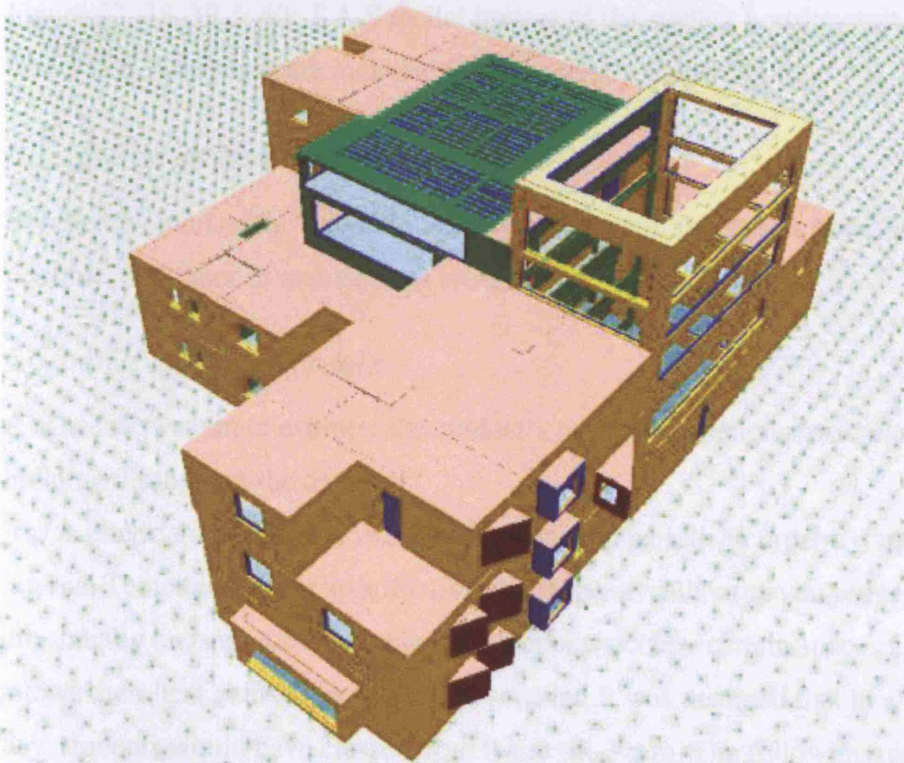
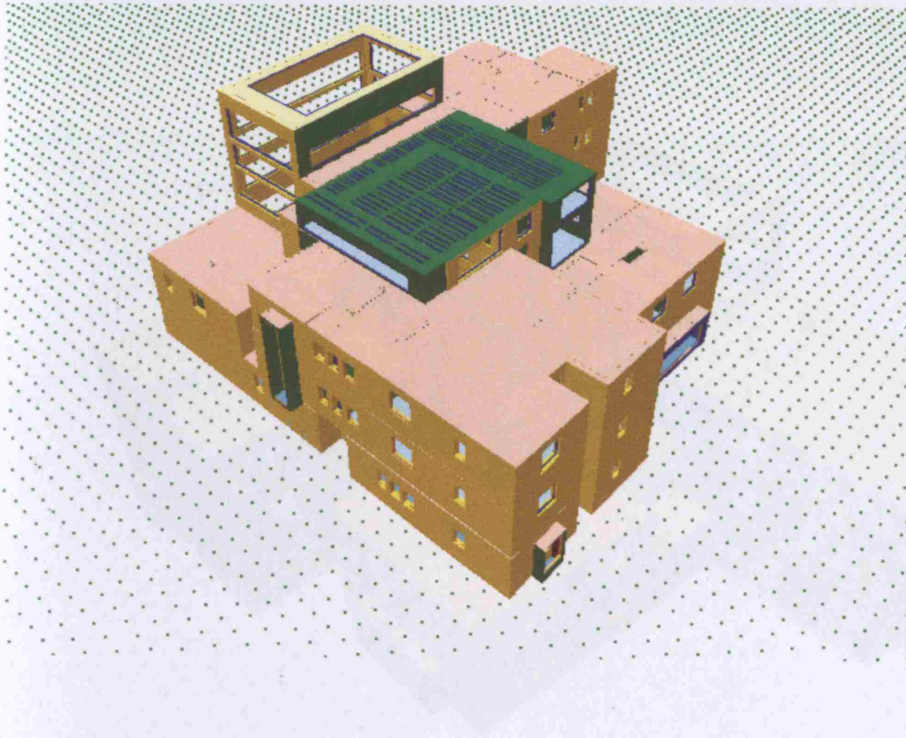
In order to assess the thermal performance of the student housing unit, a T.A.S model was built to match the existing buildings form, construction material types and



geographical location. A typical weather file was used to simulate the climatic conditions of the site.

The images below were taken from the T.A.S built model:







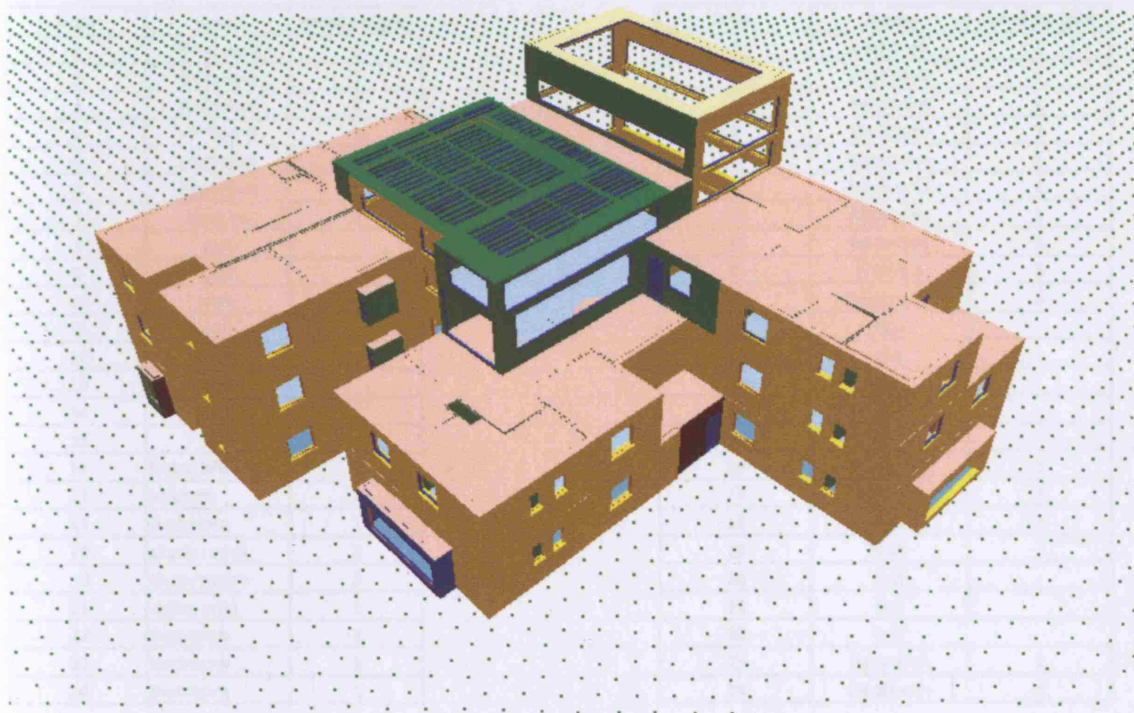


Figure 37, 38, 39 & 40: T.A.S model images of the student housing unit

The T.A.S floor plans are included in the appendix (appendix 4)

### Simulation assumptions

In order to simulate the internal thermal conditions of the spaces as accurately as possible, a number of assumptions were made:

#### 5.6.1.1 Occupancy schedule

A schedule was set to estimate the student's occupation periods for each zone of the building throughout the day.

It was important to estimate the actual occupation periods in order to target the internal Temperatures for specific times of the year, rather than targeting periods that are actually unused. Knowing when the students occupy certain spaces also allows their heat gains to be taken into account. It was assumed that in a typical week day, students would have classes from 9 a.m till-3 p.m. The following two schedules represent the student's occupancy patterns in their housing units during typical weekdays and weekends:

**week days**

hour	space	n# of people
1	Bedroom	1
2	Bedroom	1
3	Bedroom	1
4	Bedroom	1
5	Bedroom	1
6	Bedroom	1
7	Kitchen	3
8	out	
9	out	
10	out	
11	out	
12	out	
13	out	
14	out	
15	out	
16	living area	3
17	kitchen	3
18	Bedroom	1
19	study room	2
20	study room	2
21	living area	3
22	Bedroom	1
23	bedroom	1
24	Bedroom	1

Table 3: week days occupancy schedule

**Weekends**

hour	space	n# of people
1	Bedroom	1
2	Bedroom	1
3	Bedroom	1
4	Bedroom	1
5	Bedroom	1
6	Bedroom	1
7	Bedroom	1
8	bedroom	1
9	kitchen	3
10	living area	3
11	out	
12	out	
13	out	
14	out	
15	out	
16	living area	3
17	kitchen	3
18	Bedroom	1
19	out	
20	out	
21	out	
22	out	
23	bedroom	1
24	Bedroom	1

Table 4: week days occupancy schedule

**1- Weekdays:**

During week days, the student wakes up at around 6:30. He uses the kitchen for about 45 minutes, which is usually occupied by two other students for breakfast. He then heads to the university for classes, leaving the building from 8:00 a.m until 3:00 p.m. He uses the living room with two other student for about an hour, then heads to the kitchen for dinner. The student then returns to his room for an hour then uses the study room for studying with two other students for two hours. He then returns to the living room to meet friends then finally goes back to his bedroom to sleep.

**2- Weekends:**

During weekends the student wakes up at around 8:30, uses the kitchen followed by the living room for approximately an hour each. Both rooms are estimated to be occupied at that time by two more students. He then leaves the building at 11 a.m and returns back at 4 p.m where he rests at the living room for an hour followed by dinner at the kitchen for an additional hour. During that time, the living room and the kitchen expected to be occupied with two more students again. He then rests in his room for

an hour, then leaves the building for 4 hours. He then returns to sleep in his room at around 12 until the next day.

#### 5.6.1.2 Internal gains

The next step was to estimate the internal gains for each space.

The internal gains sources are metabolic gains from the occupants themselves and the heat gains produced from lighting and the equipment used in the room. The table below presents the estimated figures for heat given off by human beings in different states of activity and the expected lighting and equipment gains for each type of space.

	Office	Bedroom	Kitchen	Living room	Bathroom
Metabolic Sensible	86 w (1 person working)	79 w (1 person at rest)	86 w (1 person working)	79 w (1 person at rest)	N/A
Metabolic Latent	44 w (1 person working)	21 w (1 person at rest)	44 w (1 person working)	21 w (1 person at rest)	N/A
Lighting	10 w/m <sup>2</sup>	8 w/m <sup>2</sup>	10 w/m <sup>2</sup>	10 w/m <sup>2</sup>	8 w/m <sup>2</sup>
Equipment	10 w/m <sup>2</sup>	0 w/m <sup>2</sup>	20 w/m <sup>2</sup>	10 w/m <sup>2</sup>	0 w/m <sup>2</sup>

Table 4: internal heat gains table

#### 5.6.1.3 Lighting schedules and assumptions

Lighting gains for the house follow a similar pattern to the metabolic/equipment heat gains described above - it is assumed that lights are switched off when rooms are unoccupied. However, during daylight hours, the lights are not necessarily on. Due to the solar incidence and the courtyard organization of the building, it is assumed that the occupants will find the spaces sufficiently bright to not need artificial lighting during daytime.

#### 5.6.1.4 External door schedules

External doors are assumed to be open 3% of the time on weekdays between the hours of 8–9 am, 1–2 pm, and 5–7 pm, to simulate occupants entering/leaving the house at these times. At weekends the doors are open 3% of the time

### 5.6.1.5 Ventilation

The construction of the house was assumed to be air tight, as the construction is new and all external walls have a cavity between their construction layers. Ventilation levels were based on meeting the minimum fresh air requirement for the occupants.

### 5.6.1.6 Air conditioning for utility spaces and corridors

It was assumed that the internal corridors, toilets and storage rooms do not require any mechanical cooling/heating since the occupancy rate of these spaces are minimal

### 5.6.1.7 Construction materials:

Construction drawing sections were referred to in order to accurately simulate building materials for the model.

The figures below show detailed drawing of sections of the building:

#### 1- External walls:

External walls consist of two layers of bricks with a 50mm cavity.

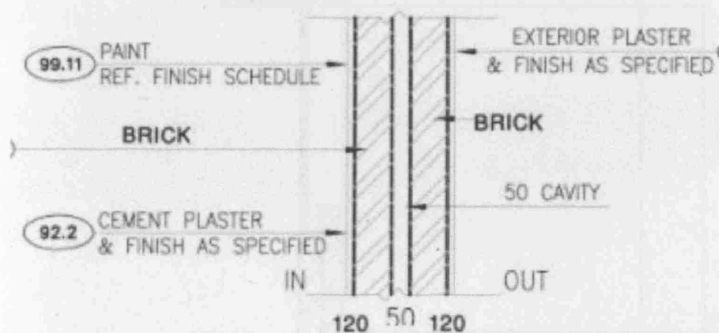


Figure 41: current external wall construction

Existing external walls U-value: **1.48 w/m<sup>2</sup> C**

Existing U-value of windows: **5.7 w/m<sup>2</sup> C**

## 2- Internal walls:

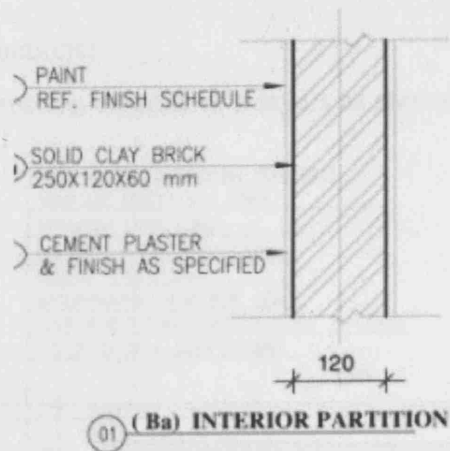


Figure 42: current internal wall construction

Existing internal walls U-value: **1.32 w/m<sup>2</sup> C**

## 3- Glazing:

The existing windows consist of a single pane of glass as shown below:

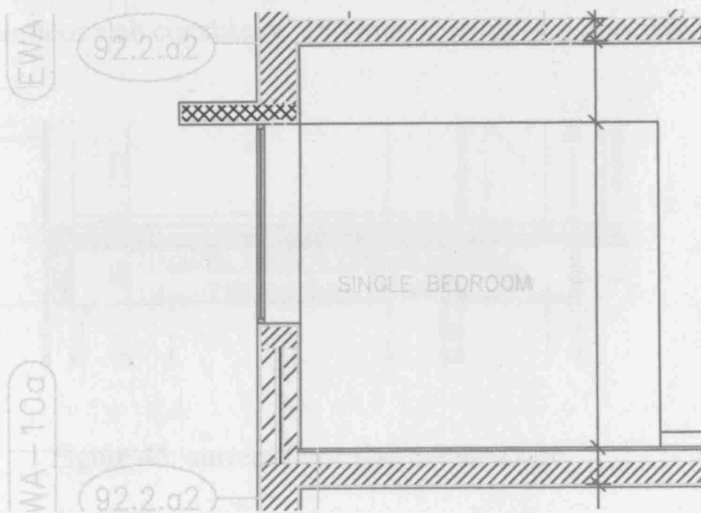


Figure 43: current window construction

Existing U-value of windows: **5.7 w/m<sup>2</sup> C**



#### 4- Roof constructions:

The roof construction consists of 8 layers as shown in the figure below:

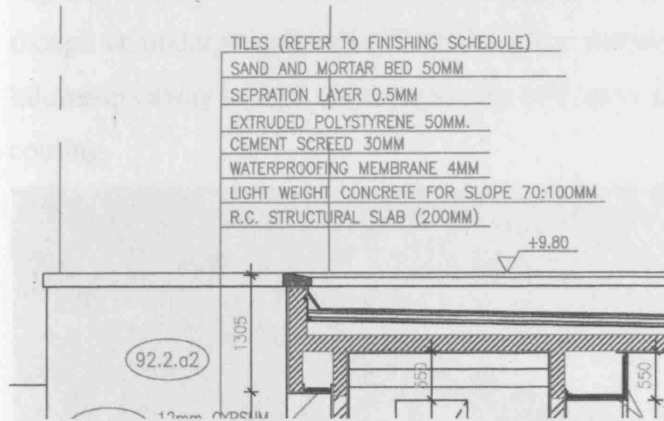


Figure 44: current roof construction

Existing U-value of Roof construction : 0.352 w/m<sup>2</sup> C

5- Floor slabs:

The floor slab consists of 150 mm of reinforced concrete with ceramic finishing.

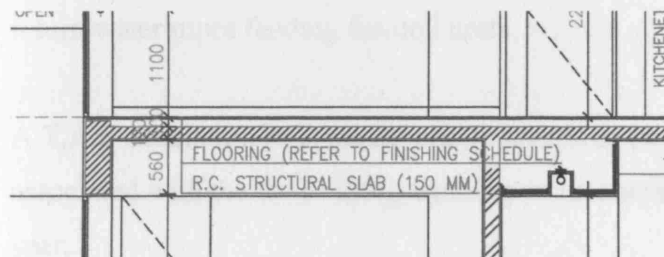


Figure 45: current floor slab construction

Existing U-value of Floor slab: **1.48 w/m<sup>2</sup> C**

### 5.6.2 Full mechanical air conditioning

In order to assess the building's current cooling and heating loads, a simulation was run with the building running on both mechanical cooling/heating. The system depends on fan coil units for heating and cooling. hot and cold water are supplied though an underground tunnel from a utility building that is approximately 4 kilometers away to feed the separate fan coil units in each space or heating and cooling.



Figure 46 : image of the fan coil unit installed in rooms  
return water pipes feeding fan coil units

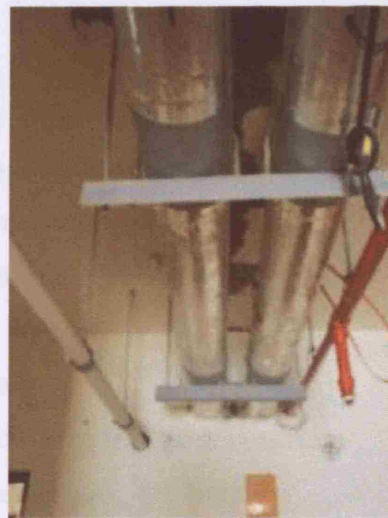


Figure 47 : supply and  
return water pipes feeding fan coil units

A T.A.S simulation was carried out to determine the cooling and heating loads associated with the the building running on mechanical air conditioning for the whole year.

The thermometer was set to start the fan coil units to heating if the temperature drops below 20 deg. c or to start cooling the space if the internal temperatures exceed 28 deg.c. It was assumed the windows would remain closed for 85 % of the time and that the buildings occupants would mostly rely on mechanical ventilation.

The simulation showed that the internal gains set for the zones (occupants, equipment and lighting loads), in addition to the windows being closed for 85% of the time, provided was sufficient to keep the requirement of mechanical heating for a large percentage of the whole year, resulting in **667 kWh/year** of heating loads. For the summer season, the cooling loads for the building's current condition needed a large

amount of mechanical cooling to keep the Temperatures below 26 degrees during occupied hours. The cooling loads required were **30379 kwh/year** . The total heating/cooling loads for the whole year were found to be **31046 kwh/year**.

The co2 emissions produced from generating the required energy to run the fan coil units for heating and cooling is  $31046 \times 0.46$  (emission factor of electricity in Egypt) = **14.3 tonnes/kwh/year**.

### 5.6.3 Mixed mode

Another simulation was conducted to assess the possibility of the building saving energy by running on mixed mode. The windows were scheduled to close at temperatures below 20 deg.c, open above 27 deg.c. If a temperature of 28 was reached, mechanical cooling would operate. If the temperature drops below 20, then mechanical heating starts to work.

Total annual cooling loads were found to be **8241 KWH/year**

A reduction of **22806 kwh/year** could be achieved if a mixed mode operating system was adopted rather than switching on to mechanical air-conditioning full time.

### 5.7 Defining the passive base case situation:

Now that the cooling/heating load of the building has been defined, the study will attempt to optimize the temperatures of the internal spaces for both the summer and winter seasons, which will in return lower the cooling load and energy consumption of the building.

The base conditions that will be taken as a reference for evaluation is the resultant internal conditions of the building's living spaces running without any mechanical ventilation and with the assumption that the windows of the building will be 40% open all of the time.

To define the annual relation of external and internal temperatures, the first floor bedrooms were selected as an example reference:

### 5.7.1 First floor bedrooms annual temperatures (windows 40% open all the time)

North facing room:

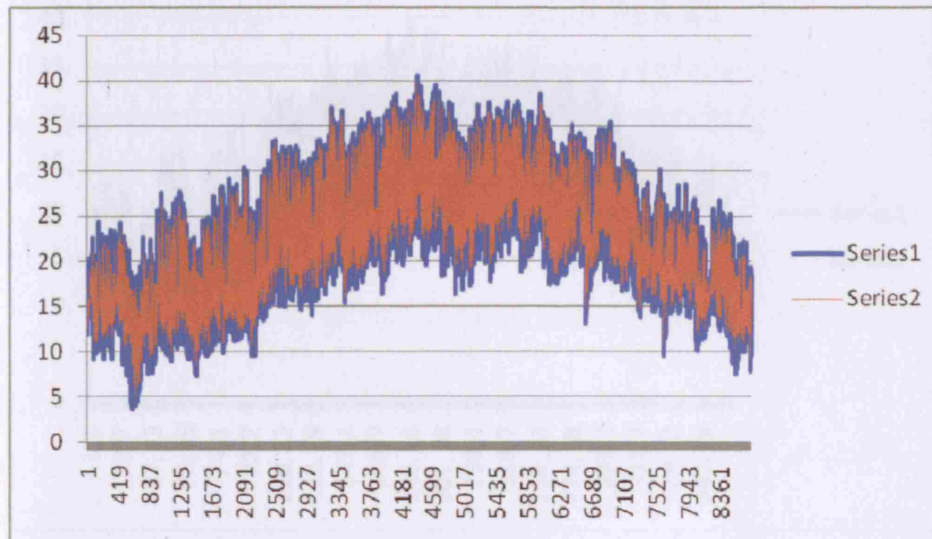


Figure 48: Annual comparison of internal and external temperatures of a north facing room

East facing room:

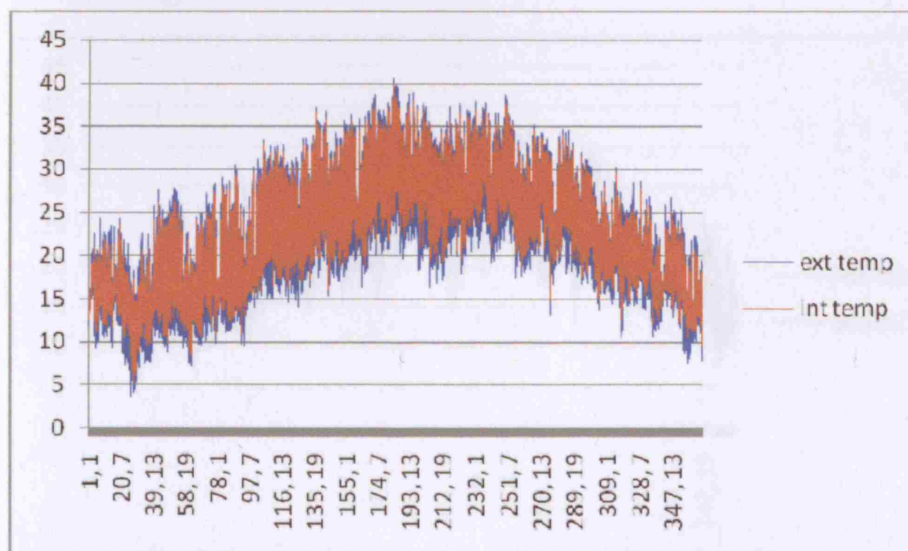


Figure 49: Annual comparison of internal and external temperatures of an east facing room

South facing room:

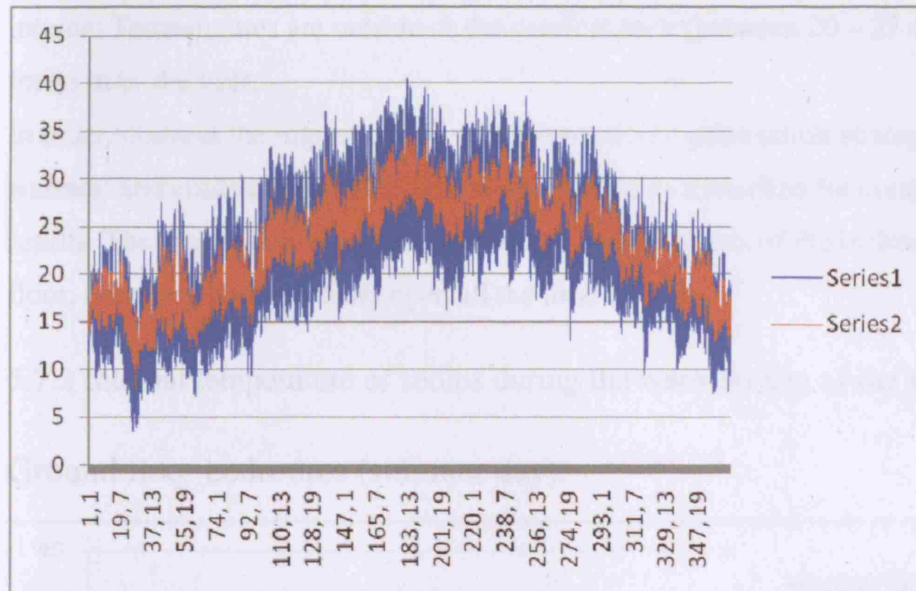


Figure 50: Annual comparison of internal and external temperatures of a south facing room

West facing room:

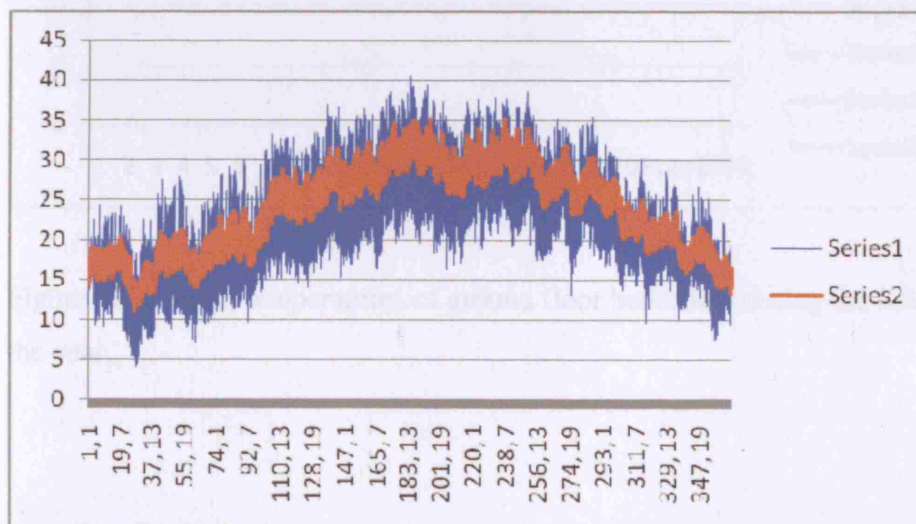


Figure 51: Annual comparison of internal and external temperatures of a west facing room



As shown from the graphs, the internal temperatures follow the external temperature fluctuations, resulting in uncomfortable internal conditions for the occupants as the internal Temperatures are outside of the comfort zone (between 20 – 27 degrees C) for most of the year.

In order to assess the impact of different temperature optimization strategies, the warmest and coldest days in the year were selected as a baseline for comparing results. The graphs below present the internal Temperatures of the bedrooms in each floor, operating with windows open all the time at 40%.

### 5.7.2 Internal temperature of rooms during the warmest day of the year

Ground floor bedrooms (summer day):

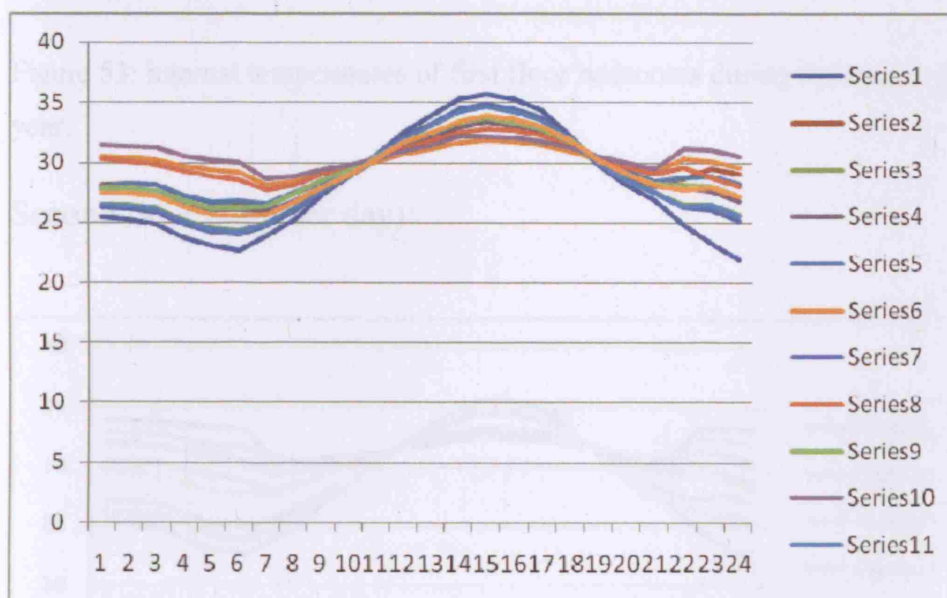


Figure 52: internal temperatures of ground floor bedrooms during the hottest day of the year.

First floor (summer day):

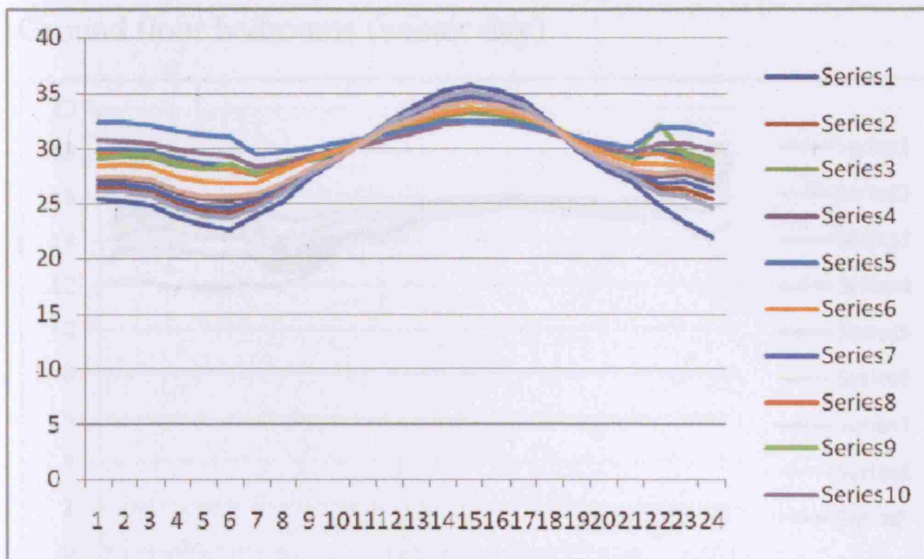


Figure 53: internal temperatures of first floor bedrooms during the hottest day of the year.

Second floor (summer day):

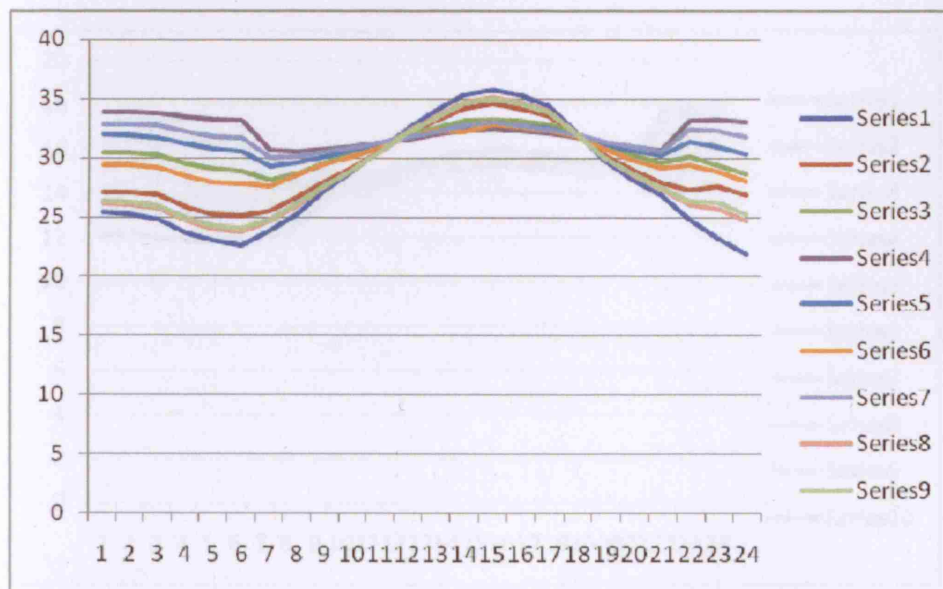


Figure 54: internal temperatures of second floor bedrooms during the hottest day of the year.



### 5.7.3 Internal temperatures during coldest day of the year

#### Ground floor bedrooms (winter day)

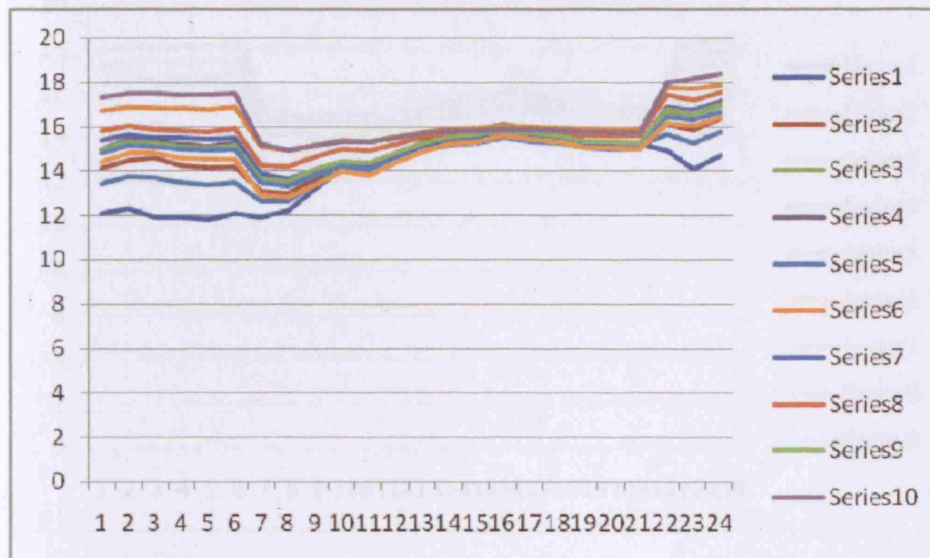


Figure 55: internal temperatures of ground floor bedrooms during the coldest day of the year.

#### First floor bedrooms (winter day)

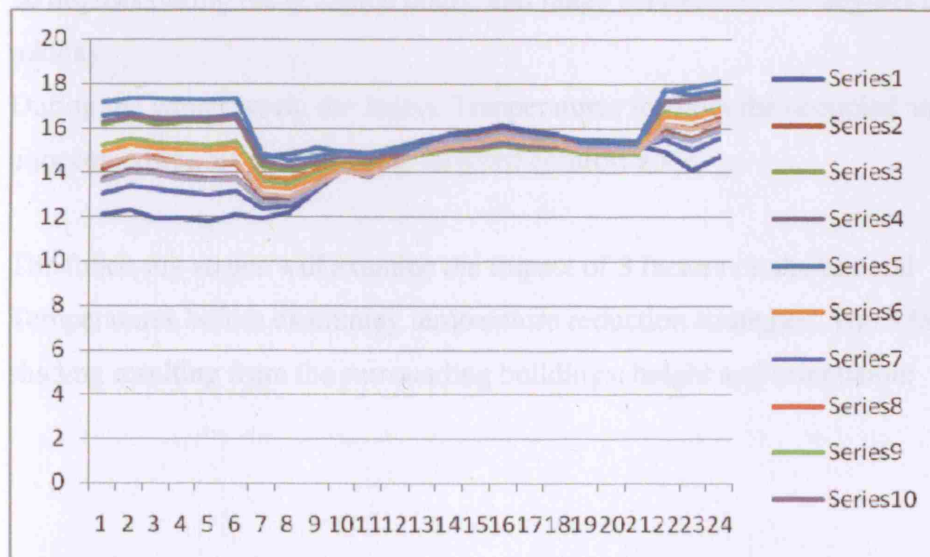


Figure 56: internal temperatures of first floor bedrooms during the coldest day of the year.

## Second floor (winter day)

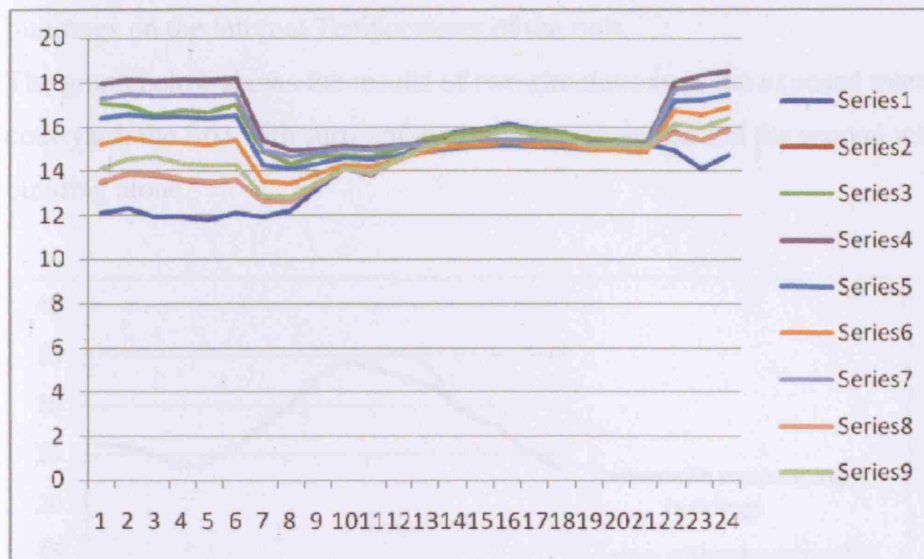


Figure 57: internal temperatures of second floor bedrooms during the coldest day of the year.

As shown from the graphs, during the summer week the majority of the rooms exceed 26 degrees during the occupied hours, and range between 30 -35 degrees during midday.

During the winter week, the indoor Temperatures for both the occupied and unoccupied spaces are below the targeted comfort zone,

The following stages will examine the impact of 3 factors on the internal Temperatures before examining temperature reduction strategies. The 3 factors are the shading resulting from the surrounding buildings, height and orientation.

### 5.7.3 Effect of surrounding buildings

A series of T.A.S simulations were conducted to define the impact of the surrounding buildings on the internal Temperatures of the unit.

The graph below shows the results of two simulations of the exposed internal courtyard, the first with surrounding buildings included and the second with the building alone.

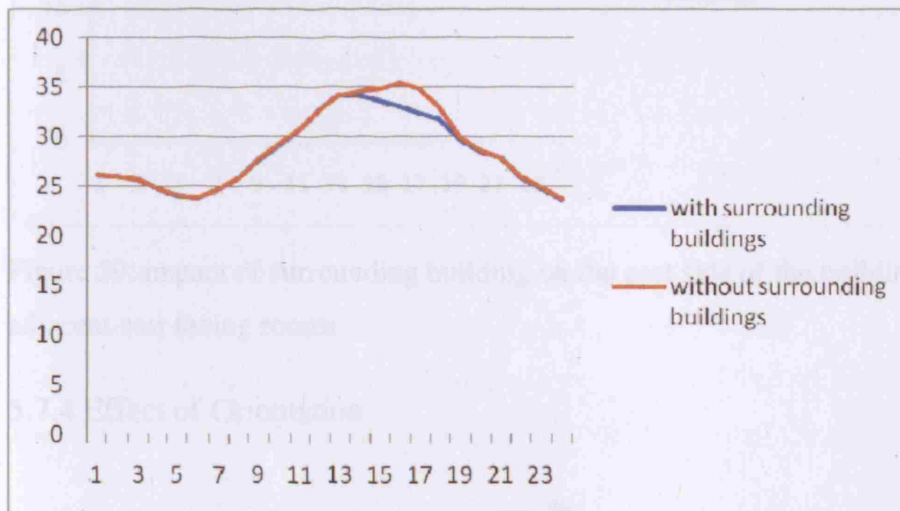


Figure 58: impact of surrounding building on the west side of the building on the adjacent west facing rooms

The results show that the shading of the surrounding buildings on the western facade of the unit resulted in a temperature reduction that reached a peak of 2.5 degrees .C at 3p.m during day 240 .

On the other hand the building on the east side of the unit had minimal impact on the adjacent internal spaces, mainly because the building on the east side is shifted towards the south, making it too far away for the impact of its shadows to be significant.

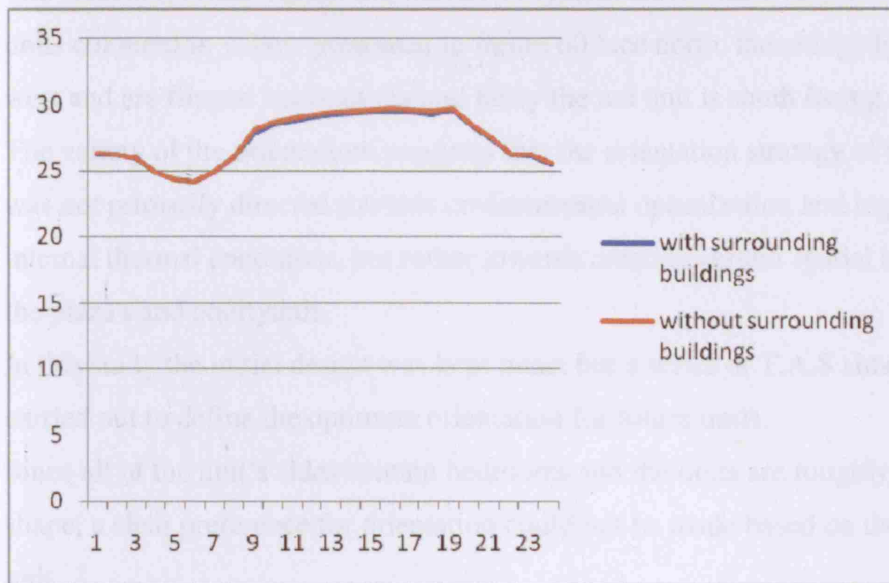


Figure 59: impact of surrounding building on the east side of the building on the adjacent east facing rooms

#### 5.7.4 Effect of Orientation

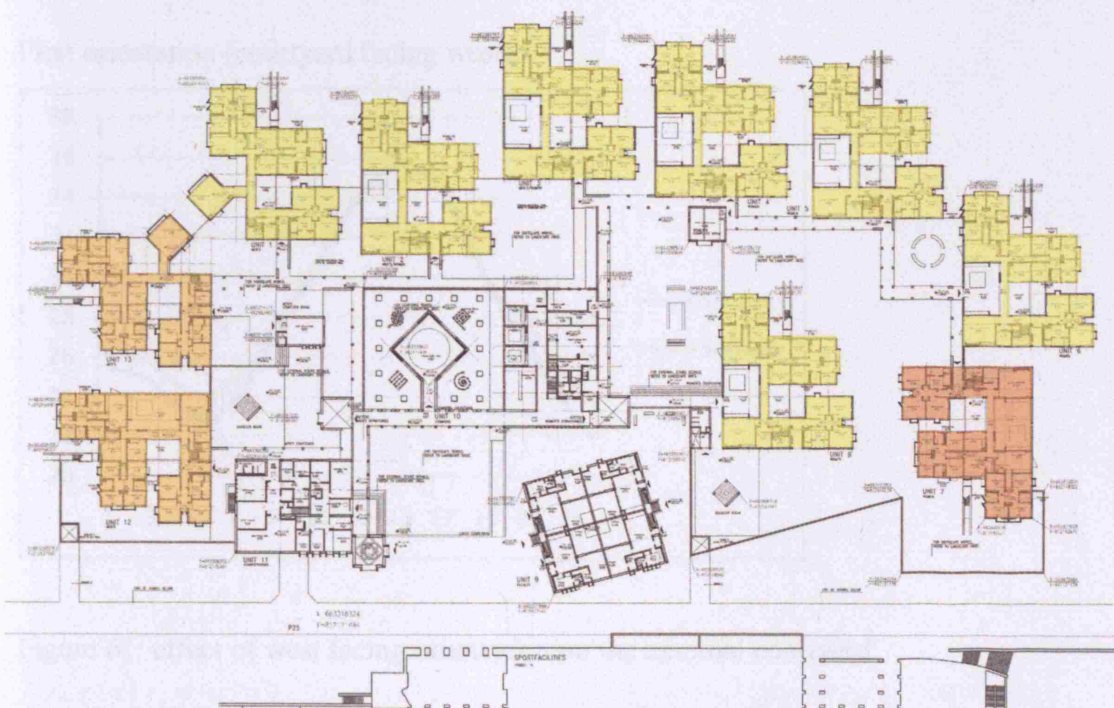


Figure 60: cluster layout showing three types of orientations



The student housing cluster consists of 11 typical units which vary in orientation. The units coloured in yellow presented in figure 60 face north, the orange buildings face west and are flipped horizontally and lastly the red unit is south facing.

The variety of the orientations suggests that the orientation strategy of the buildings was not primarily directed towards environmental optimization and improving internal thermal conditions, but rather towards creating certain spatial organization for the plaza's and courtyards.

In this study the initial design was kept intact but a series of T.A.S simulations were carried out to define the optimum orientation for future units.

Since all of the unit's sides contain bedrooms and the units are roughly square in shape, a clear preference for orientation could not be made based on the form of the unit.

The internal courtyards were selected for thermal analysis as they play a significant role in affecting the surrounding internal spaces Temperatures.

3 simulations were carried out: to assess the impact of orientation on the exposed courtyard temperature fluctuations during the warmest day of the year.

First orientation (courtyard facing west):

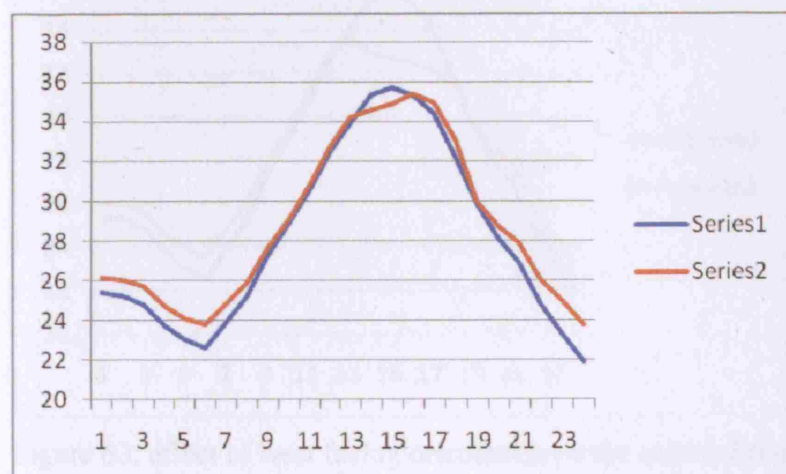


Figure 61: effect of west facing orientation on the external courtyard

Second orientation (courtyard facing east):

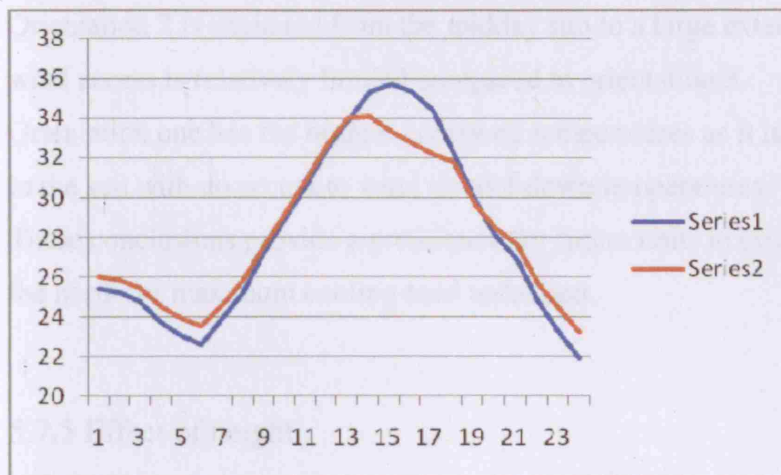


Figure 62: effect of east facing orientation on the external courtyard

Third orientation (courtyard facing north):

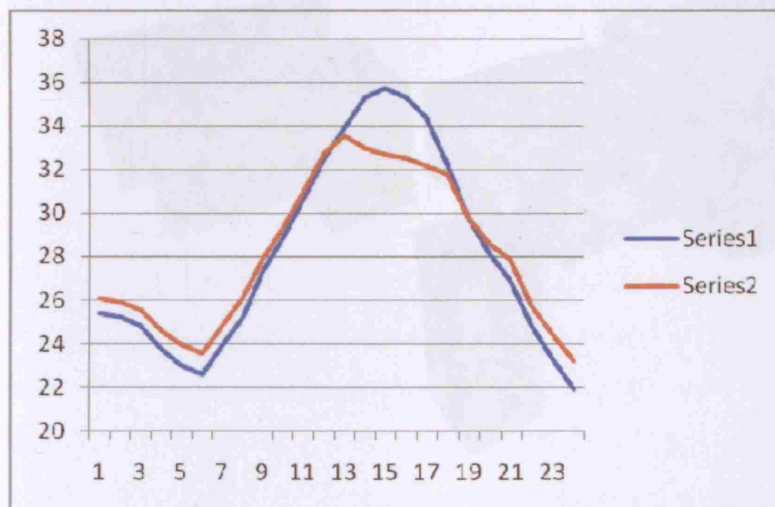


Figure 63: effect of west facing orientation on the external courtyard

The results show that orientation 3 resulted in the lowest temperatures followed by orientation 2 and 1 respectively.

This is basically because orientation 3 positions the courtyard to face north, which has the lowest exposure to the intense midday sun. Exposing the courtyard to the north



also allows exposure to the prevailing northern summer wind, which helps in reducing fluctuating external temperatures.

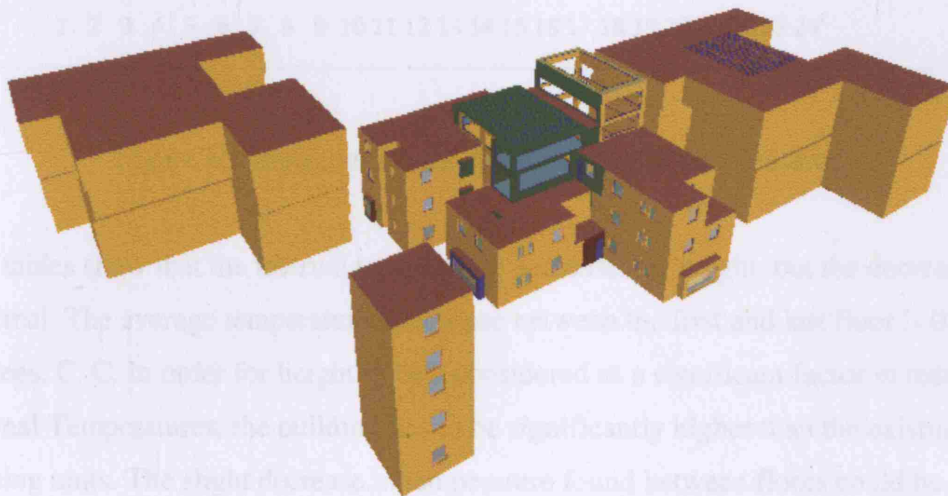
Orientation 2 is sheltered from the midday sun to a large extent, but prevailing north wind access is relatively limited compared to orientation 3.

Orientation one has the highest courtyard temperatures as it is west facing, exposing it to the sun with no access to wind to cool down temperatures.

These conclusions provide a preference for future units to orient the courtyard to face the north for maximum cooling load reduction.

### 5.7.5 Effect of height

In order to access the impact of height on internal Temperatures independently, a T.A.S box model was built with 5 floors :



ready

Figure 64: T.A.S model for assessing the impact of height on internal temperatures

The table below shows the internal temperature of the rooms of the model for each floor.

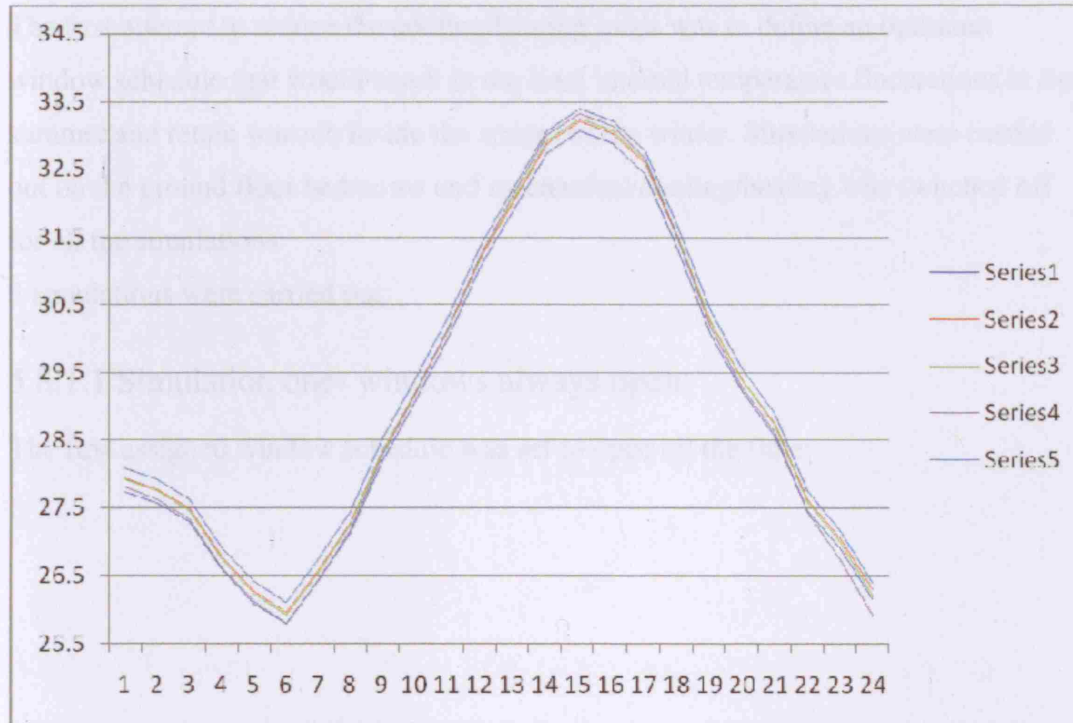


Figure 65: impact of height on internal room temperatures

The tables show that the internal temperature decreases by height, but the decrease is minimal. The average temperature difference between the first and last floor is 0.5 degrees. C. C. In order for height to be considered as a significant factor in reducing internal Temperatures, the building has to be significantly higher than the existing housing units. The slight decrease in temperature found between floors could be a result of the ground floor being exposed to more diffuse radiation from the surrounding landscape, which have reflective, bright colours. Another possible reason may be due to the decreasing outside temperature with altitude within the troposphere. One of the options that could be considered is to raise the units on posts, creating an open space underneath the ground floor where wind could pass and cool the floor slab and provide a shaded area for interaction below the units.

## 5.8 Strategies for internal temperature optimization:

### 5.8.1 Window schedules:

The first attempt to reduce the cooling/heating loads was to define an optimum window schedule that would result in the least internal temperature fluctuations in the summer and retain warmth inside the spaces in the winter. Simulations were carried out on the ground floor bedrooms and mechanical cooling/heating was switched off for all the simulations

3 simulations were carried out:

#### 5.8.1.1 Simulation one- windows always open:

The first assigned window schedule was set to open all the time:

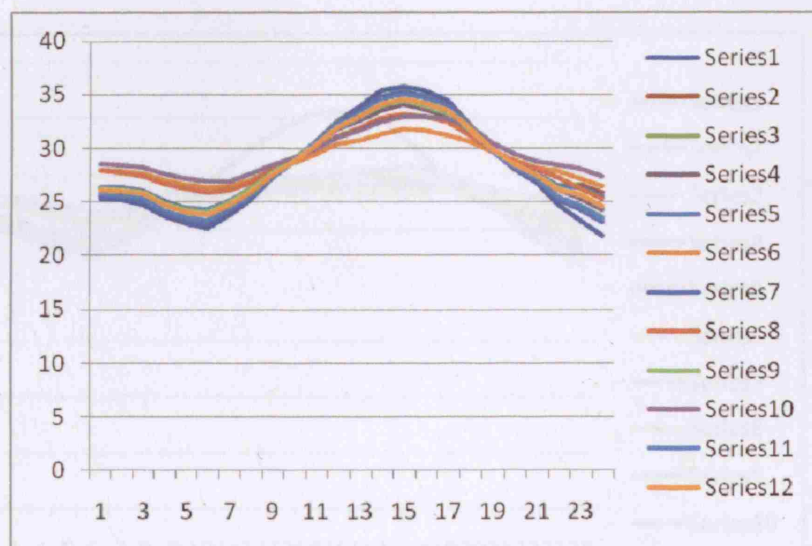


Figure 66: internal temperatures of Ground floor bedrooms with windows open all the time

### 5.7.1.2 Simulation 2- windows open all the time (40% open):

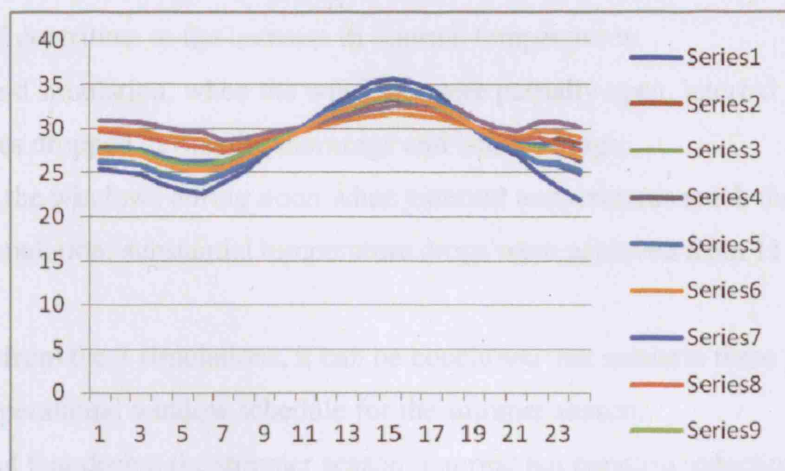


Figure 67: internal temperatures of Ground floor bedrooms with windows 40 % open all the time

### 5.8.1.3 Simulation three- night ventilation and windows shut during the day:

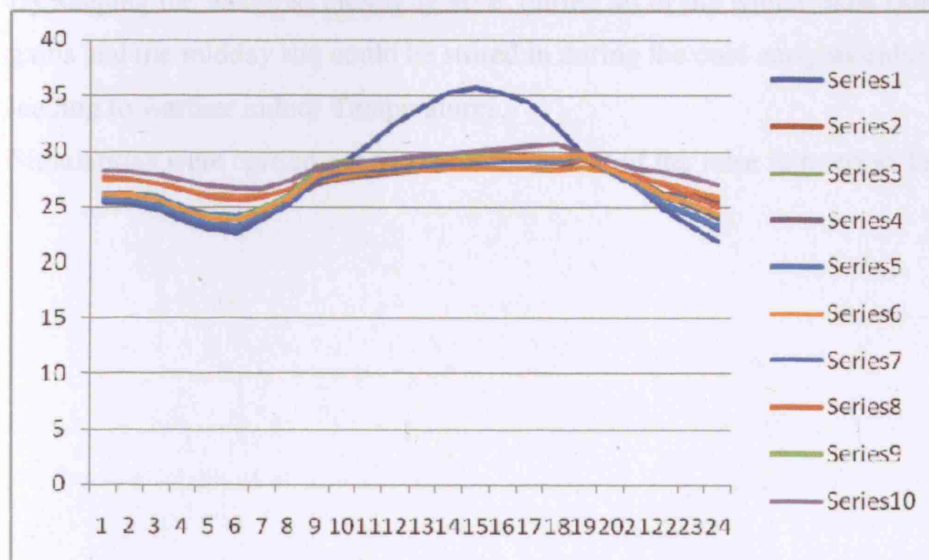


Figure 68: internal temperatures of Ground floor bedrooms with night ventilation and windows shut during the day:

By setting the windows to be always open in the first simulation, the external air losses its cooling capacity after a certain temperature, and any air entering from outside will contribute to the increase in internal temperatures.

In the second simulation, when the windows were partially open, internal temperatures dropped during the mornings and late evenings.

By closing the windows during noon when external temperatures reach their peak in the third simulation, substantial temperature drops were achieved from 11 a.m until 8 p.m.

Therefore, from the 3 simulations, it can be concluded that scenario three presents the optimum operational window schedule for the summer season.

It was found that during the summer season, internal temperature reduction in spaces were achieved when the windows were closed during midday (from 12 p. m till 5 p.m) when the external temperatures reached its peak, and opened during night to allow for night ventilation. The cool night wind would enter the spaces the cool off the heat gains stored in the thermal mass of the ceilings and internal walls, cooling the rooms for the rest day.

#### 5.8.1.4 Winter window schedule:

By keeping the windows closed by 90%, during all of the winter, heat from internal gains and the midday sun could be stored in during the cold early mornings and nights leading to warmer indoor Temperatures.

Simulations were carried out to access the extent of the raise in internal Temperatures:



Ground floor:

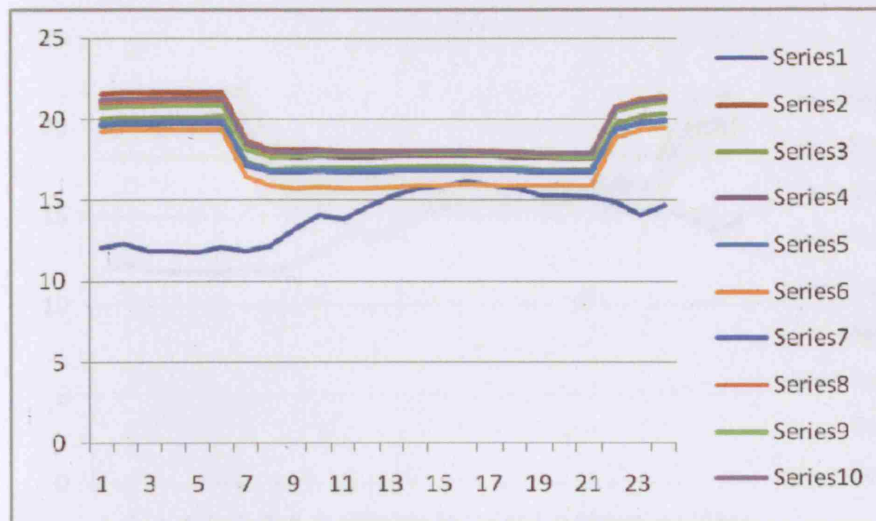


Figure 69: impact of closing windows of ground floor bedroom temperatures during the coldest day of the year

First floor:

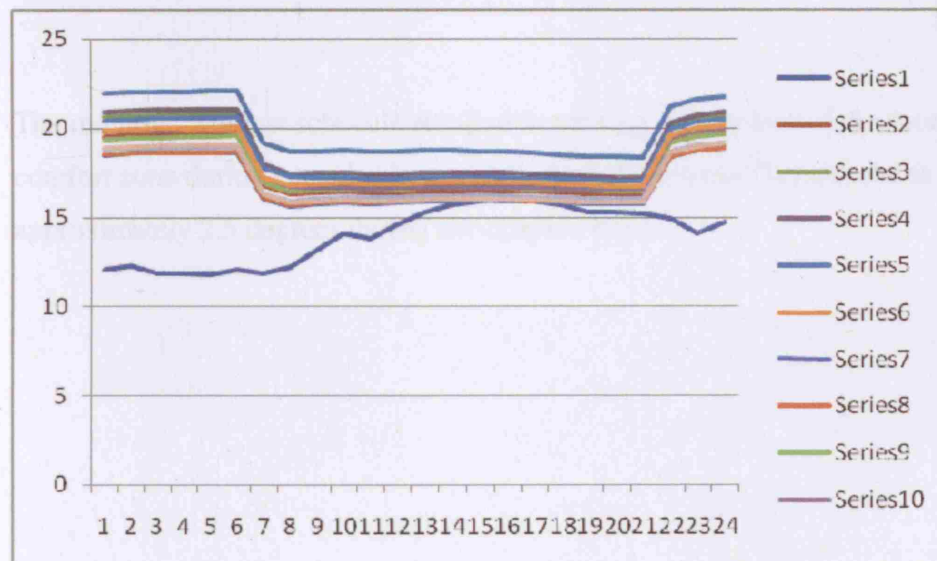


Figure 70: impact of closing windows of first floor bedroom temperatures during the coldest day of the year



Second floor:

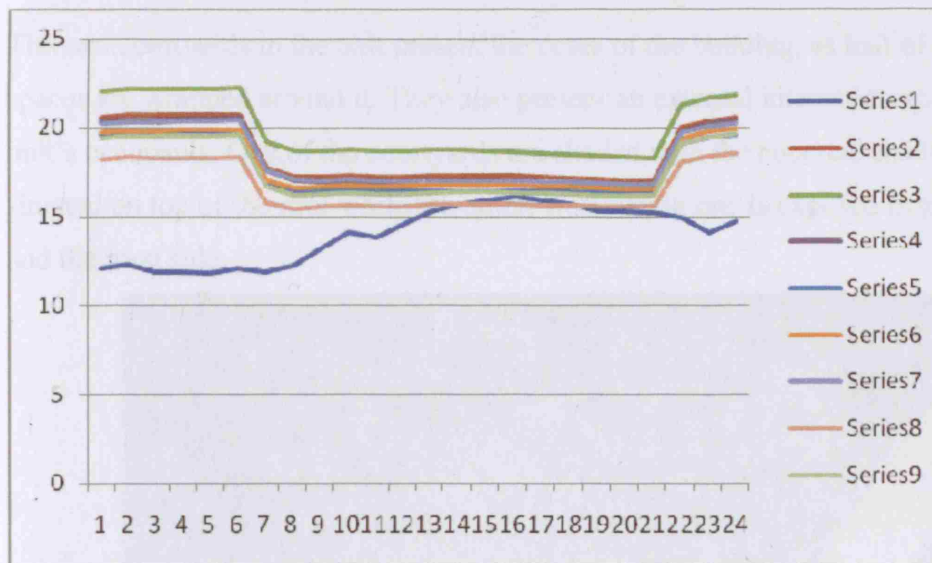


Figure 71: impact of closing windows of first floor bedroom temperatures during the coldest day of the year

The modified window schedule resulted in moving almost half of the rooms inside the comfort zone during occupied hours and raised the internal Temperatures approximately 2.5 degrees during unoccupied hours.

### 5.8.2 Integration of courtyard tensile structure cover:

The two courtyards in the unit present the cores of the building, as half of the living spaces are wrapped around it. They also present an external interaction space for the unit's occupants. One of the courtyards are shaded with the concrete shading slab situated on top of the roof while the other, west facing one is exposed from the top and the west side.



Figure 72: shaded courtyard at 2 p.m, June 2008



Figure 73: Unshaded courtyard at 2 p.m, June 2008

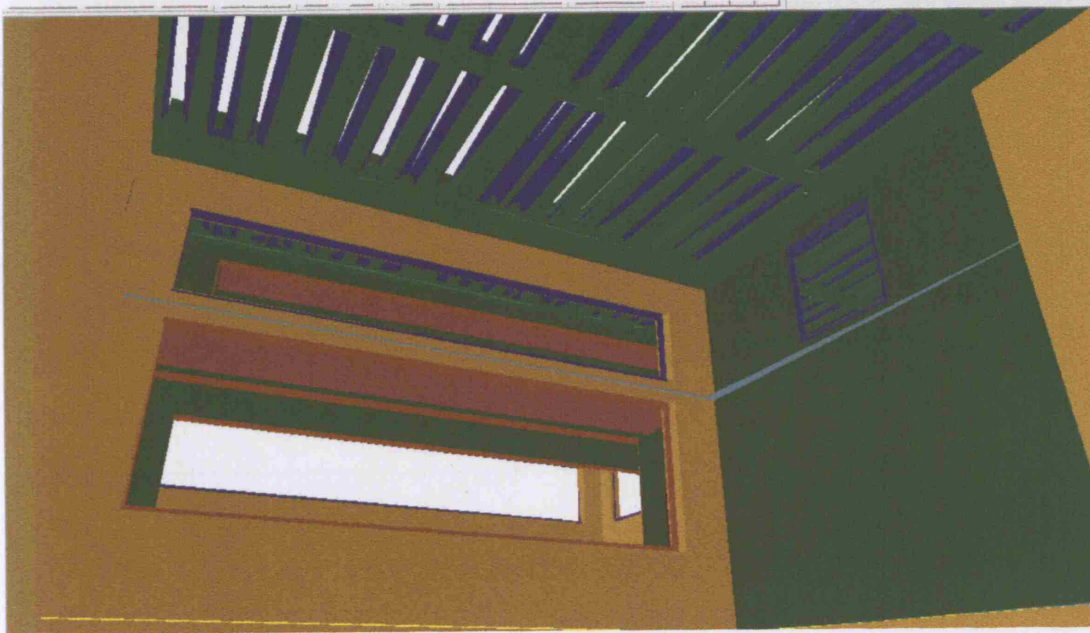


Figure 74: T.A.S model of shaded courtyard

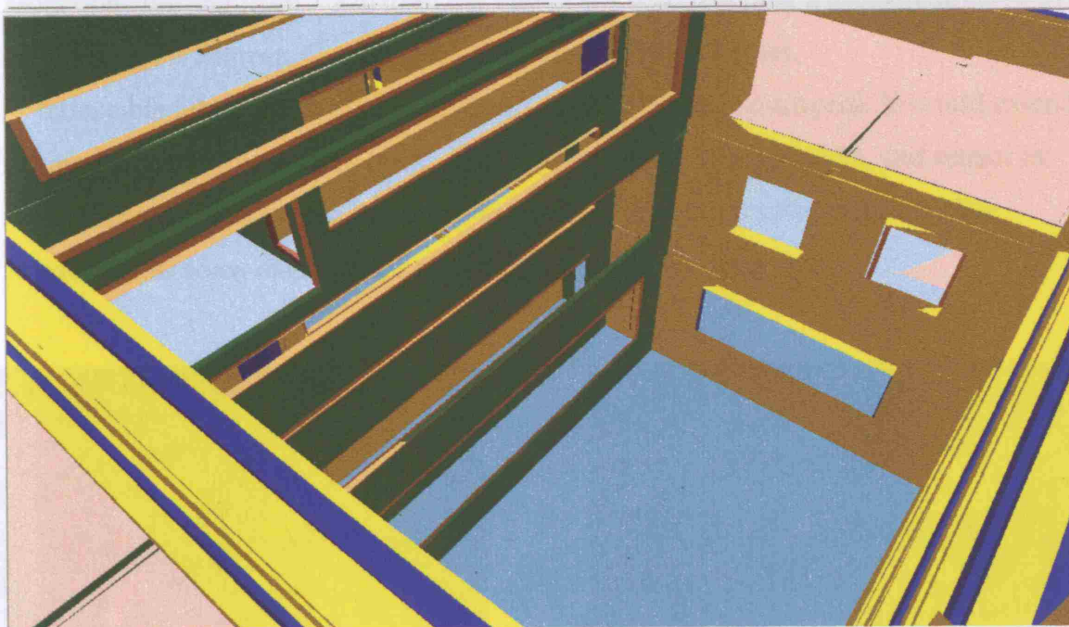


Figure 75: T.A.S model of unshaded courtyard



A simulation was run to assess the temperature difference between the exposed and shaded courtyards:

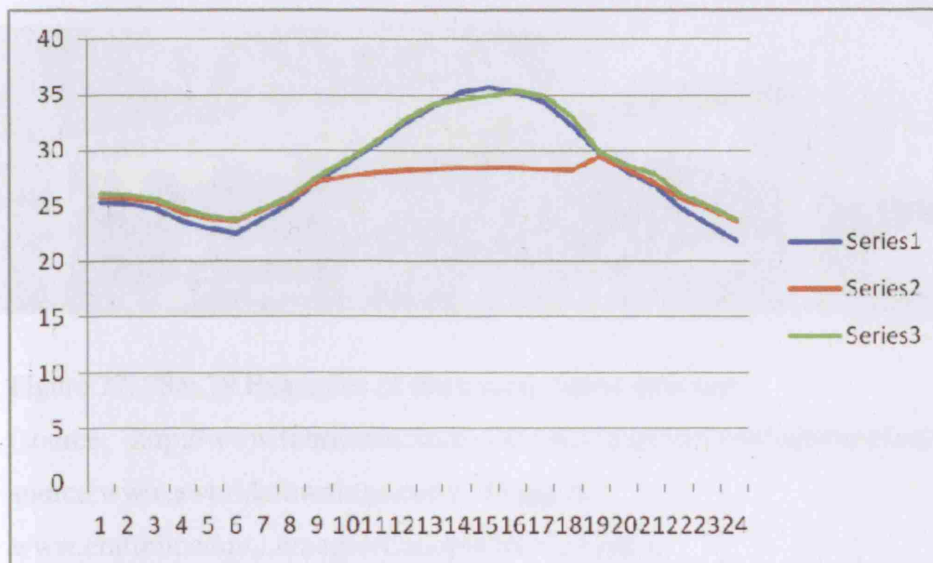


Figure 76: Difference in temperature between the shaded and unshaded courtyards

As shown from the graph, the shaded courtyard results in substantial temperature reductions starting from 7 a.m. until the end of the day, reaching a temperature difference of 8 degrees. C at the peak temperature hour (3 p.m).

A retractable fabric structure was assigned to the unshaded courtyard. It would extend during the summer season to bring down the courtyard Temperatures, and retract in the winter season to expose the courtyard to the desired sun solar radiation. The images below show examples of retractable shading fabric devices:





Figure 77, 78& 79 Examples of retractable fabric structure

(source: <http://www.fabricstructures.com.au/images/hi-res/Salt-Int-North.jpg> ,

source: [www.aworldofawnings.com/.../3.jpg](http://www.aworldofawnings.com/.../3.jpg) &

[www.craftbilt.com/.../images/CanopyOpening.jpg](http://www.craftbilt.com/.../images/CanopyOpening.jpg) )

The chart below presents the temperature differences between the court with the retractable fabric structure and the existing exposed condition

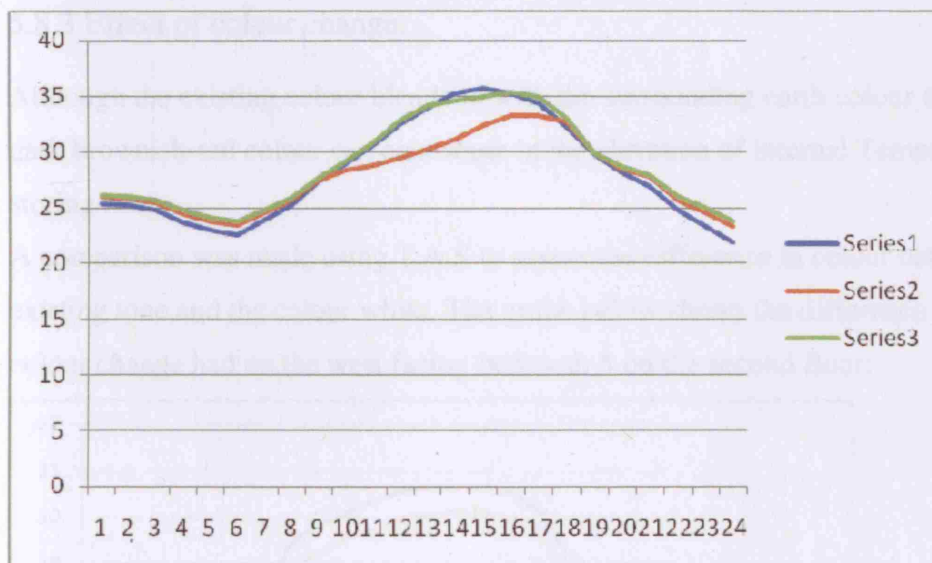


Figure 80: temperature difference between shaded and unshaded courtyard

As shown from the graph, the tent structure managed to decrease the courtyard's temperature below the external temperature during noon, reaching a maximum reduction of 3 deg. C at 12.p.m, when the sun rays reached the maximum intensity and are perpendicular on the courtyard.



The temperature drop in the courtyard has resulted in a temperature drop in the surrounding internal spaces. The graphs below show temperature drops in the ground floor study room and bedroom number 3.

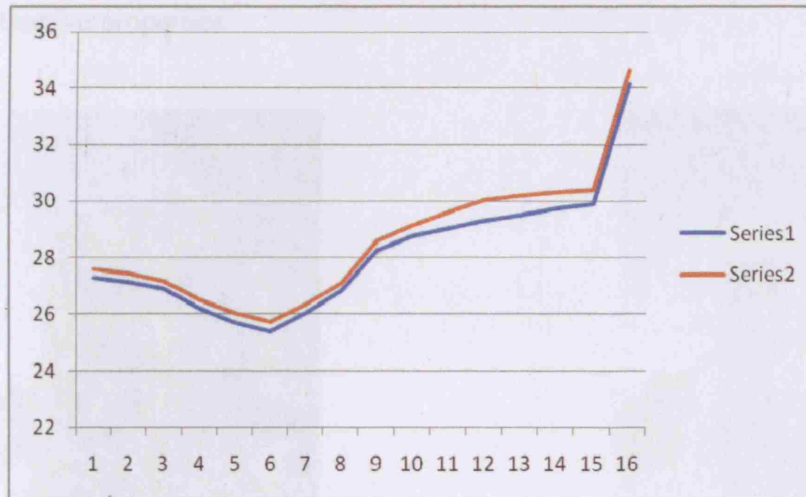


Figure 81 Effect of courtyard fabric cover on adjacent rooms

### 5.8.3 Effect of colour change:

Although the existing colour blends in with the surrounding earth colour tones, its dark brownish-red colour can contribute in the elevation of internal Temperatures by storing heat.

A comparison was made using T.A.S to assess the difference in colour between the existing tone and the colour white. The graph below shows the difference that the colour change had on the west facing bedroom 5 on the second floor:

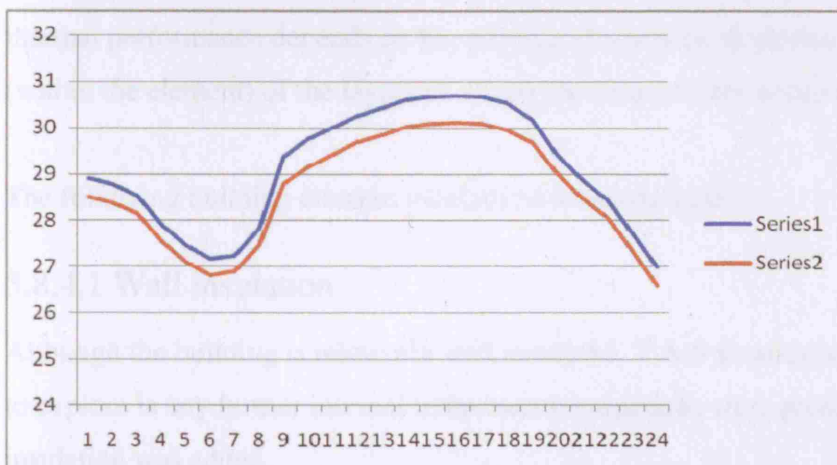


Figure 82: Effect of colour change on bedroom 5 on the second floor

As shown from the graph, an internal temperature drop of an average of 1 deg.C can be achieved if the colour of the external walls changed to white due to the colour's reflective properties.



#### 5.8.4 Insulation

Materials are organised in buildings to form elements with certain thickness: the envelope of the building (exterior walls and the roof) and the interior elements (internal partitions and floors).

Each element is composed of a number of layers of different materials. The compositions of the different layers in the envelope have a significant impact on the thermal performance of the buildings. Thus, the effect of the building elements on the thermal performance depends on the physical properties, thickness, and location (within the element) of the layers of which the elements are composed.

The following building element insulations were examined:

##### 5.8.4.1 Wall insulation

Although the building is relatively well insulated, T.A.S simulations were carried out to explore if any further internal temperature reductions were possible if more insulation was added.

The existing wall construction, which had a u-value of 1.47 w/m<sup>2</sup> C was compared to the same assembly, but with insulation in the 50 mm cavity, which could be possibly added if it proved to be effective.

The walls were then compared to another wall construction that had a 100 mm cavity with insulation, a composition that could be used for future units if it proved to result in significant internal temperature reductions.

By adding 50 mm and 100 mm of insulation, the external walls u-values decreased to 0.52 w/m<sup>2</sup> C and 0.31w/m<sup>2</sup> respectively.

The following chart shows the internal temperature difference caused by adding 50 mm cavity

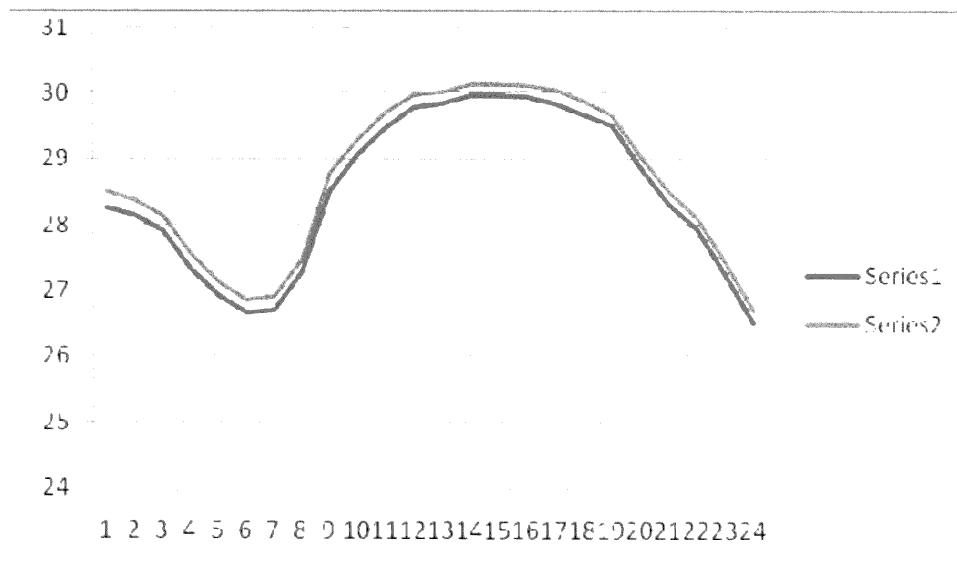


Figure 83: impact of 50 mm external wall insulation

The graphs show that a further reduction of an average of 0.5 degree.C is possible if insulation is added to the existing cavity.

Comparison between the 50 mm and 100 mm insulation:

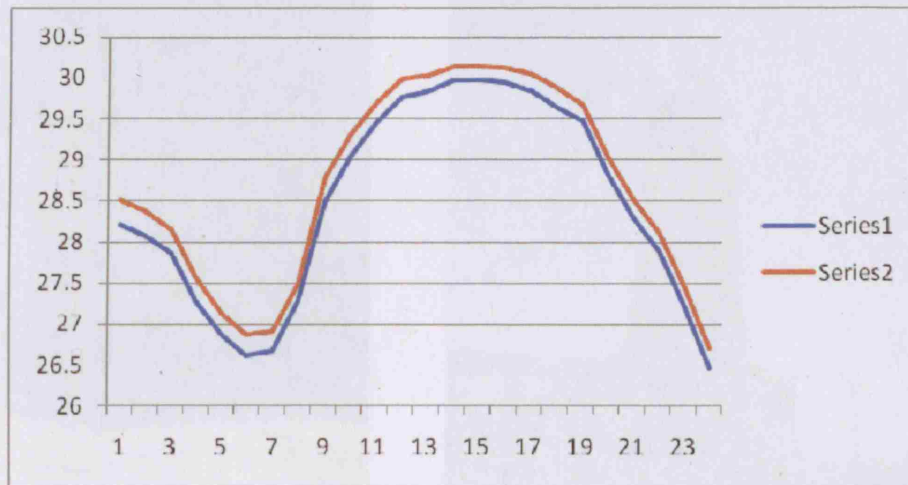


Figure 84: comparison between 50 mm and 100 mm external wall insulation

As shown from the graph, the impact of the difference between the 50 mm and 100 mm is minimal on internal Temperatures; therefore the additional costs of the extra insulation and constructions are unjustifiable.

#### 5.8.4.2 External wall material change:

Most of the campus's buildings have a stone cladding, which give the campus the character of an old Cairo city. The stone cladding also serves the purpose of adding an additional layer of thermal insulation to the external walls. By adding stone cladding, the external walls u-value decreased to 0.2 w/m<sup>2</sup> C.





Figure 85 & 86: examples of campus buildings that have external stone cladding

A T.A.S simulation was carried out to assess the impact of adding stone cladding to the external walls of a south facing room:

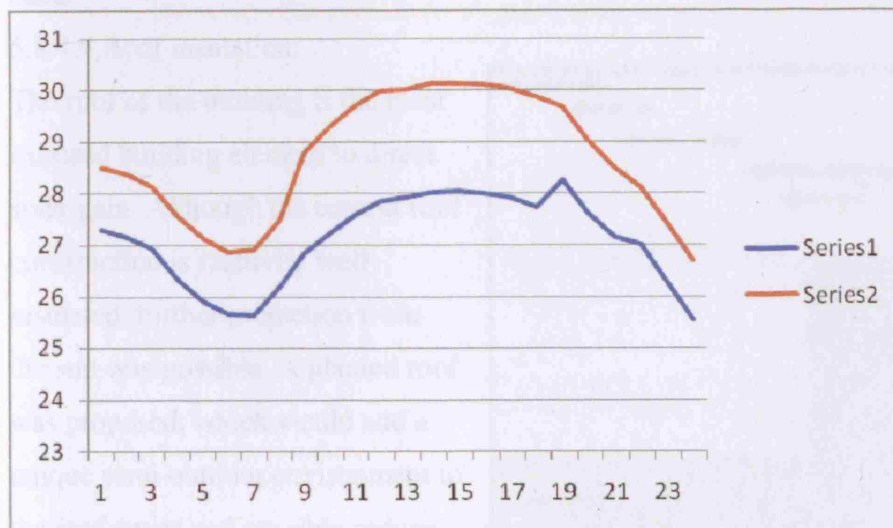


Figure 87: impact of stone cladding

The chart show that the stone cladding contributed in significant temperature reductions, even more effective than adding internal insulation to the existing cavity.



#### 5.8.4.3 Floor insulation:

By adding floor, the u-value of the floors decreased to from 1.479 w/m<sup>2</sup> C to 0.142 w/m<sup>2</sup> C.

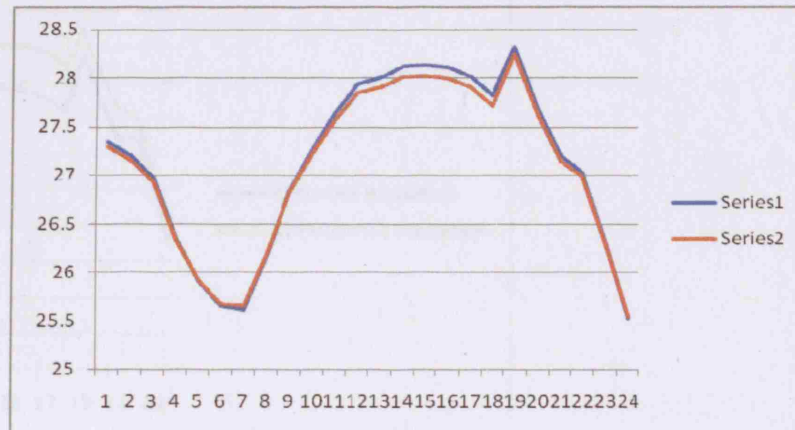


Figure 88: impact of floor insulation

Floor insulation resulted in minimal internal temperature reductions as shown in the figure above. This is mainly due to the approximate equality in internal Temperatures between rooms. i.e., all of the rooms in different floors have similar internal heat gains, so over heating due to heat transfer between vertically adjacent rooms do not occur

#### 5.8.4.4 Roof insulation:

The roof of the building is the most exposed building element to direct solar gain. Although the current roof construction is relatively well insulated, further protection from the sun was possible. A planted roof was proposed, which would add a unique semi-outdoor environment to the roof space and possibly reduce the the impact of solar radiation.

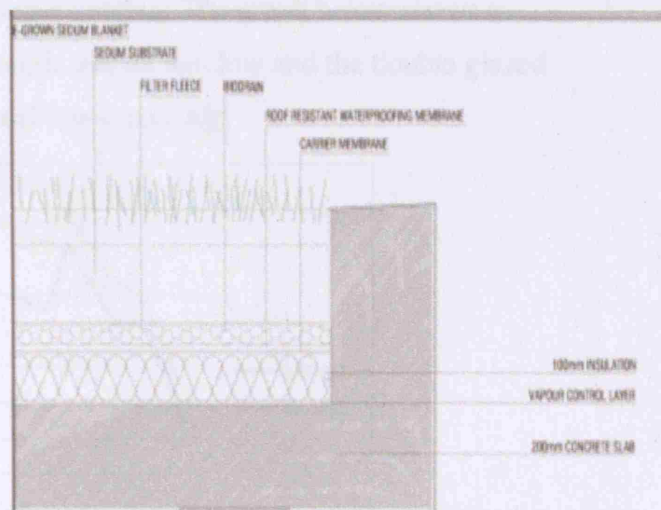


Figure 89: example of planted roof

By planting the roof, the u-value would drop from 0.3 w/m<sup>2</sup> C to 0.18 w/m<sup>2</sup> C

The graph below demonstrates that an average of 0.5 deg.C could be achieved if further insulation is applied to the roof.

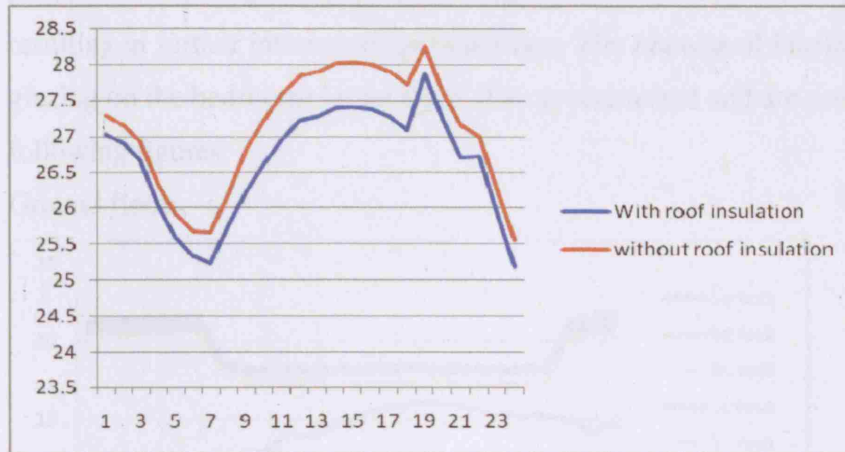


Figure 90: Impact of roof insulation

### 5.8.5 Glazing

Although the existing building envelope construction is quite air tight, the single glazed windows result in a series of thermal bridges in the building, allowing gained coolth and heat to escape the internal spaces.

The single glazed windows were substituted with double glazed windows with argon gas filling the cavity and an external low-e coating. The graph below shows a comparison between the impact of a single glazed window and the double glazed substitute with argon filling and external low-e coating:

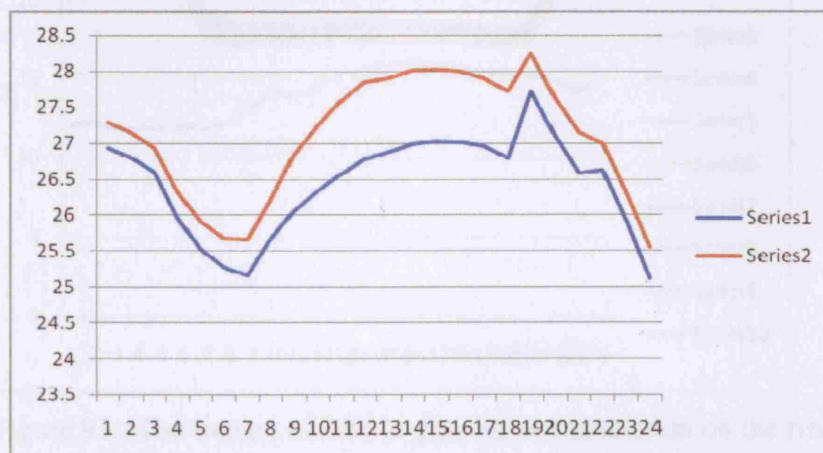


Figure 91: comparison between the impact of double and single glazing on internal temperatures

### 5.8.6 Impact of insulation and glazing on the winter schedule:

By adding insulation to the building envelope and replacing the existing window panes with double glazing, further storage of the absorbed heat could be sustained, resulting in further internal temperature rise. The impacts of insulation and improved glazing on the bedrooms in the three floors were tested and are presented in the following figures:

Ground floor:

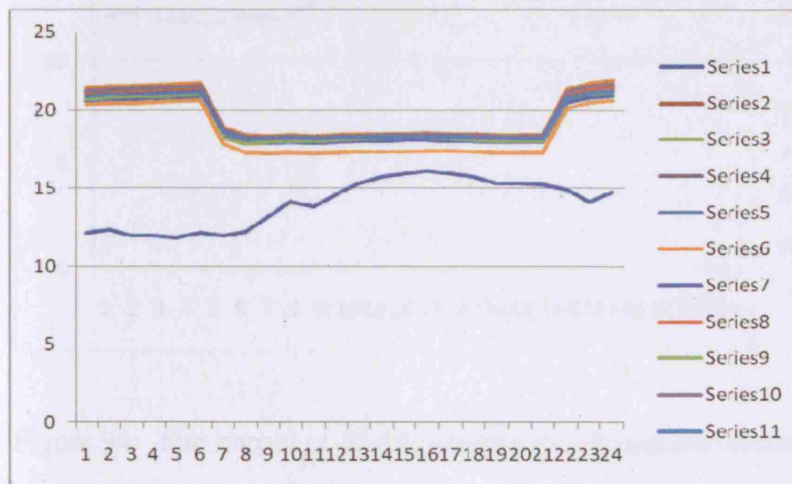


Figure 92: The impact of double glazing and insulation on the ground floor internal temperatures

First floor:

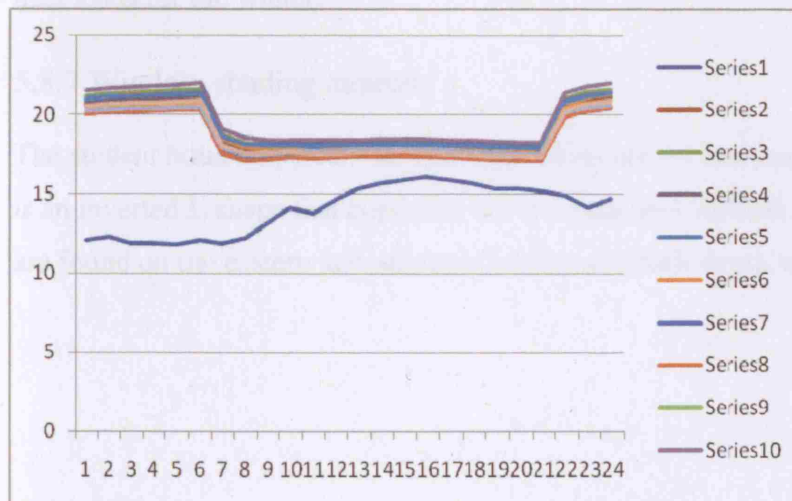


Figure 93: The impact of double glazing and insulation on the first floor internal temperatures

Second floor:

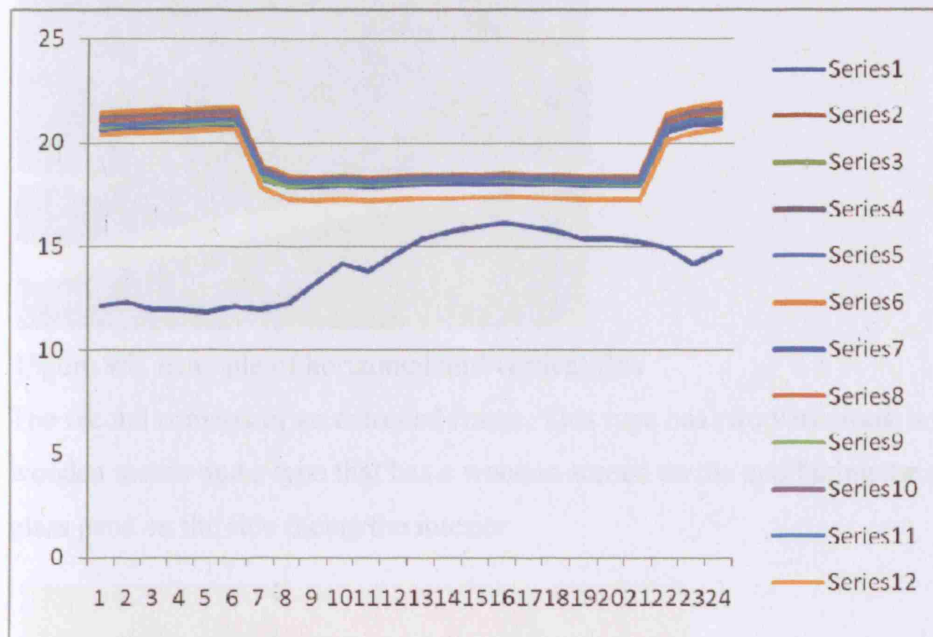


Figure 94: The impact of double glazing and insulation on the second floor internal temperatures

As shown from the graphs, the temperature rise resulted in positioning all of the bedrooms inside the targeted comfort zone during occupied hours, eliminating any heat loads for the winter.

#### 5.8.7 Window shading analysis

The student housing parcel has four main elements for shading its openings. The first is an inverted L shape that combines a horizontal and vertical fin together. These fins are found on the eastern and western facades and their depth was set to 0.7 m.



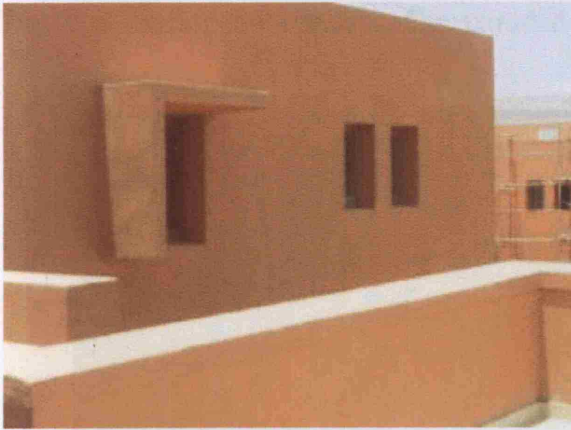


Figure 95: example of horizontal and vertical fins

The second consists of an extruded frame. This type has two variations; a type with no wooden screen and a type that has a wooden screen on the end facing the street and a glass pane on the side facing the interior.



Figure 96: Example of extruded frame



Figure 97: Example of extruded window frame with a wooden screen (*mashrabiya*)



The third shading tool consists of an extruded window that has side openings

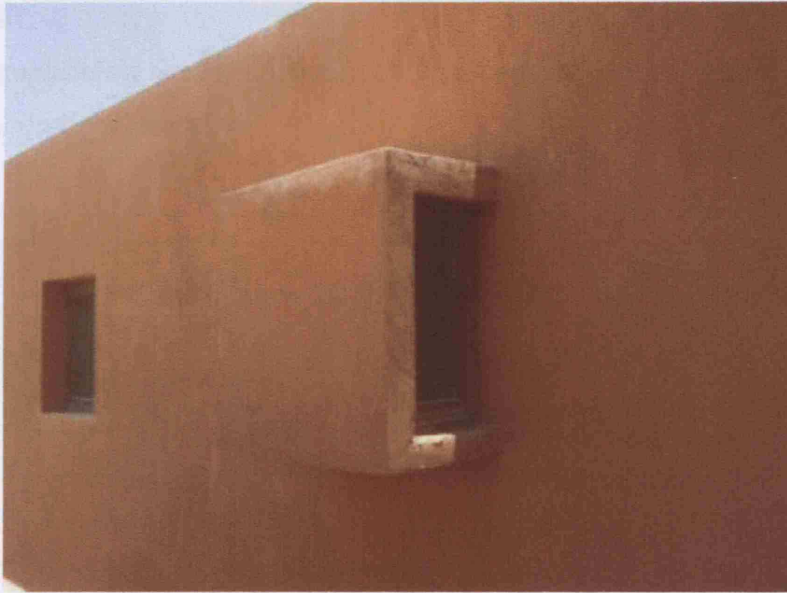


Figure 98: Example of extruded window with side openings

The fourth and last type is the tilted, extruded window. These types are found on the western facade. Four of these windows are facing south, while one is facing the north, suggesting that no particular consideration to the sun and wind orientation was given.

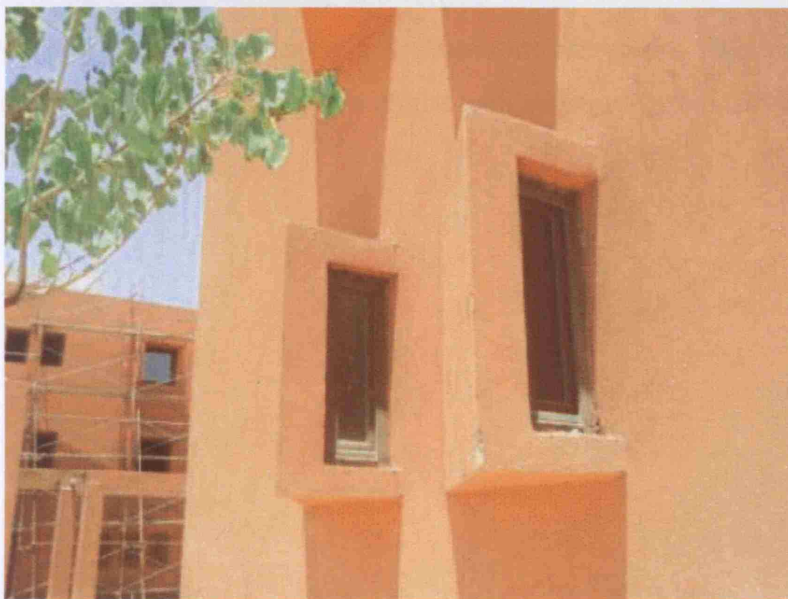


Figure 99: example of tilted extruded windows

To order to quantitatively define the effectiveness of the existing window shading elements, a series of simulations were conducted using the solar tool software and T.A.S.

The graph below shows the impact of horizontal and vertical shading fins of windows in the southern facade.

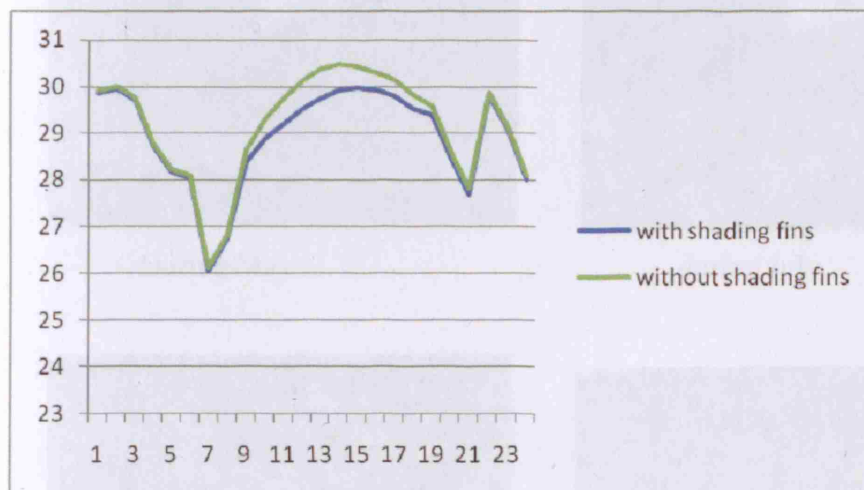
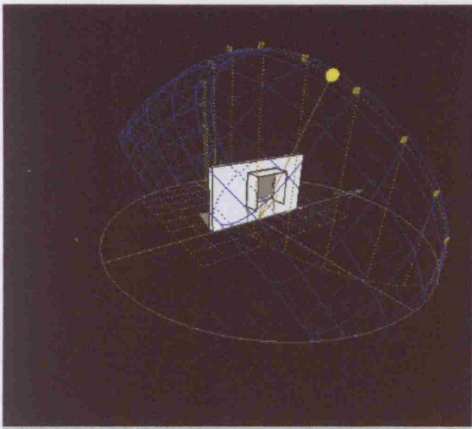


Figure 100: Comparison between internal temperatures with and without horizontal and vertical fins

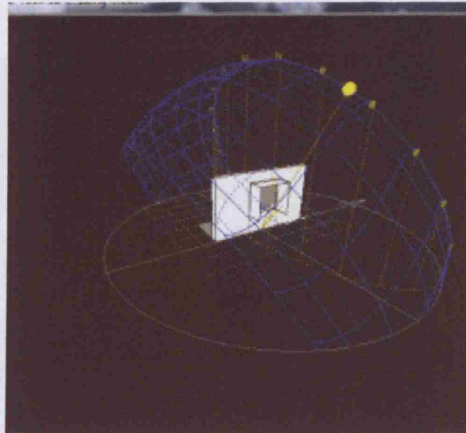
A series of simulations were then conducted on the solar tool software to analyze the effect of the existing horizontal and vertical L-shaped shading louvers found on the eastern and southern facades for the whole summer season. The images below present the effect of the shading elements on the windows throughout different months of the summer season:



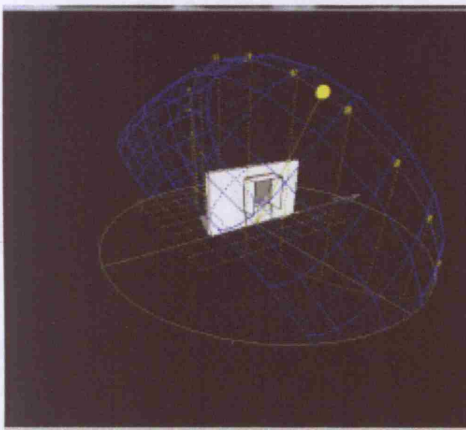
Louvers on the east facing facade:



During May

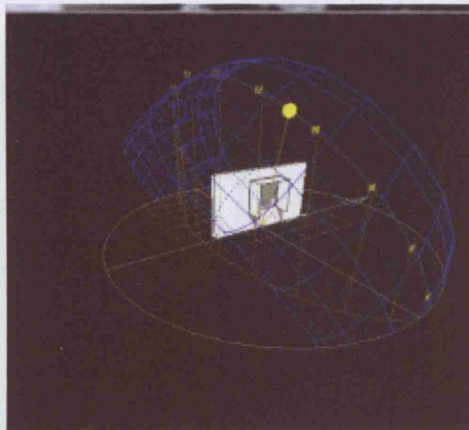


during July

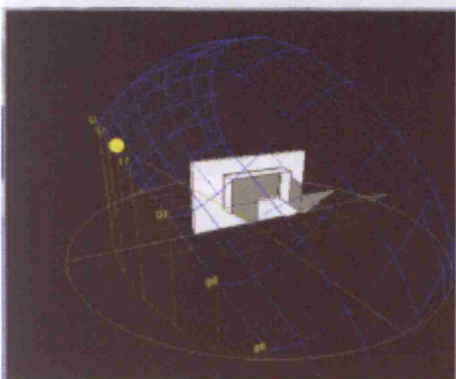


model - hold CTRL to pan, SHIFT to zoom, SHIFT+CTRL to change perspective distance...

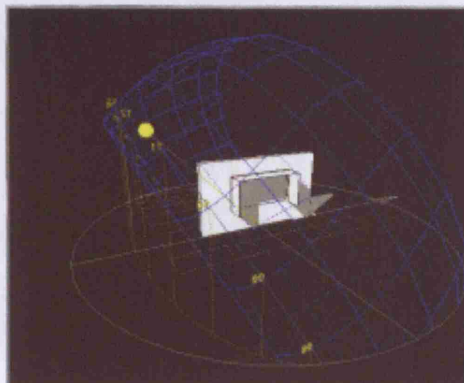
During August



during September

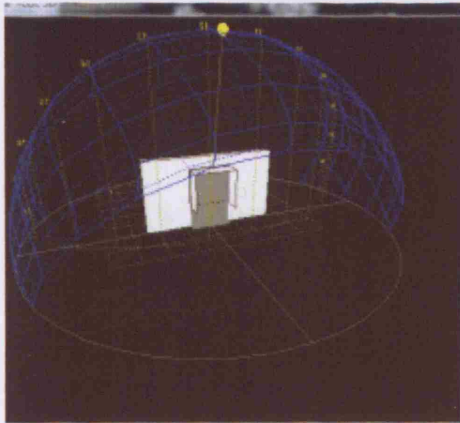


During January

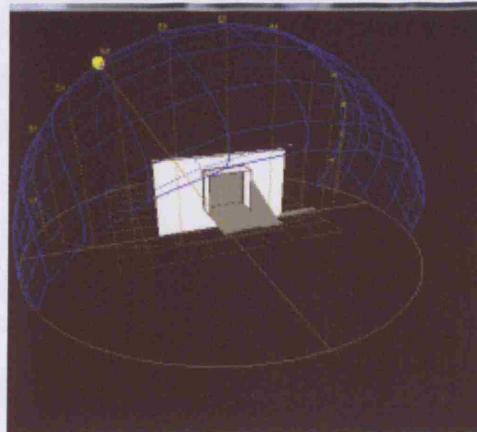


during February

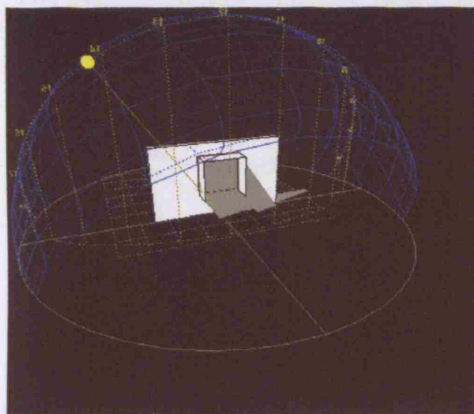
Louvers on the south facing facade:



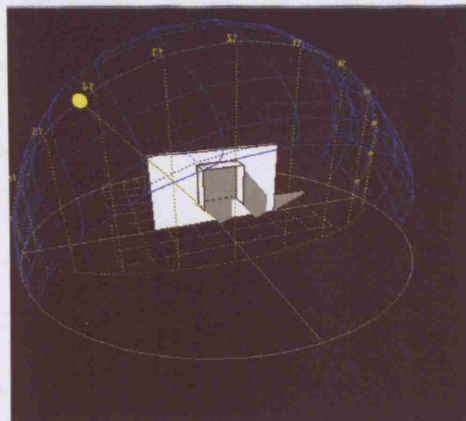
During May



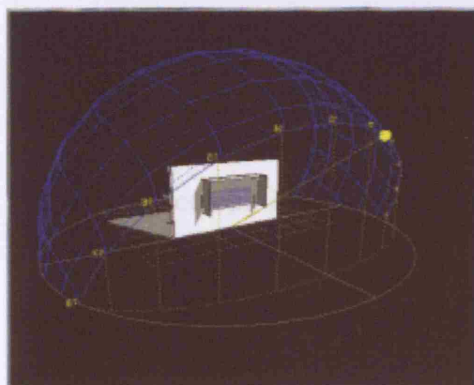
during July



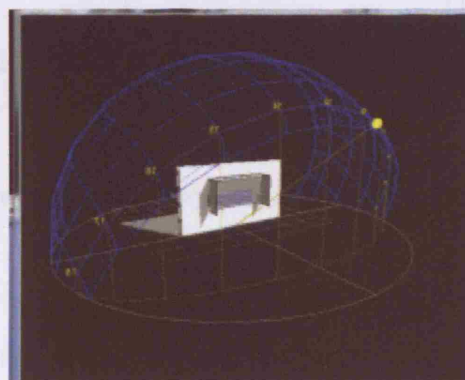
During August



during September



During January



during February



As shown in the previous images of the solar tool simulations, the existing fins are sufficient in blocking the high sun angles of the summer sun on both the eastern and western facades. However, during winter, when the sun angle is low and morning and midday solar radiation is desirable, the vertical fins on the eastern facades and the horizontal fins on the southern facades block a large percentage of the windows.

### Extruded windows:

Next, a simulation was conducted to assess the efficiency of the extruded windows on the west facade.

A room was simulated three times in T.A.S, firstly, without any window treatment, secondly with an extruded frame, thirdly with an extruded and tilted frame facing north.

The combined results of the simulation are presented in the following graph:

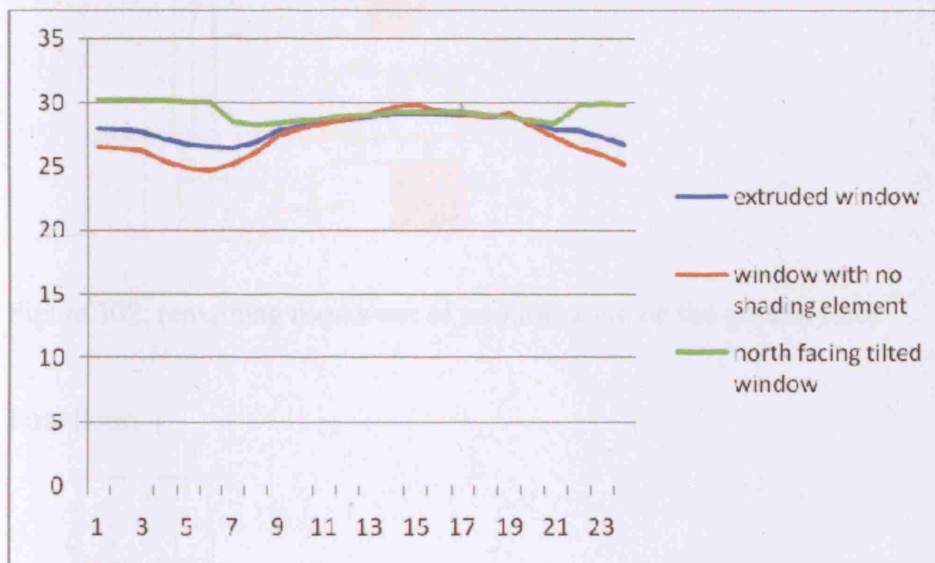


Figure 101: comparison between different types of window shading elements

As shown from the graph, both window treatments actually resulted in higher internal temperatures during morning and evenings. Even though both elements block direct access of solar radiation; they also limit the entrance of wind, which reduces the internal gains

The tilted window's opening was too small to allow in sufficient air to cool the internal spaces, while the extruded windows frame block wind coming in from the north.



The best option for window shading would be an element that provides shading from solar radiation but at the same time does not obstruct wind entrance into rooms.

#### 5.8.8 Progress analysis:

At this point in the process, most of the rooms fell within the comfort zone during their occupied schedules. The figure below shows the remaining rooms that experience internal Temperatures that are out of the comfort zone:

Ground floor:

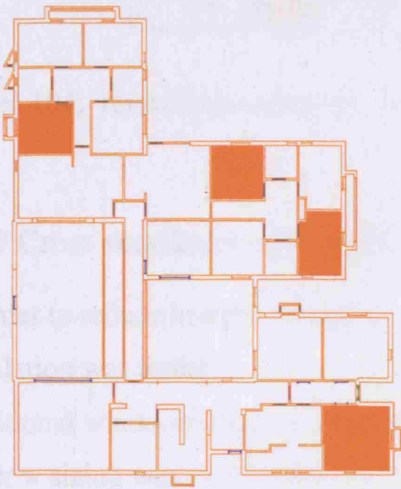


Figure 102: remaining rooms out of comfort zone on the ground floor

First floor:

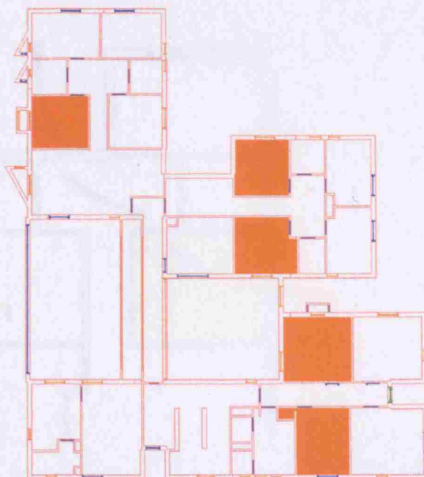


Figure 103: remaining rooms out of comfort zone on the first floor

Second floor:

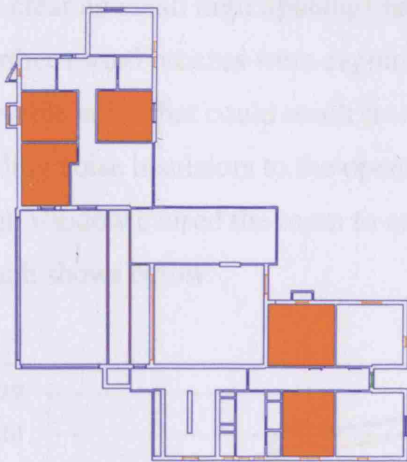


Figure 104: remaining rooms out of comfort zone on the second floor

### 5.8.9 Cross ventilation and window sizing:

In order to reduce internal temperatures from the rooms defined above, cross ventilation was tested.

Additional windows were created in the walls opposite to existing windows and window sizing was carried out to achieve the maximum effectiveness possible.

The section below demonstrates examples of applying cross ventilation to the bedrooms that were out of the comfort zone on the second floor.

Rooms 6 & 7:

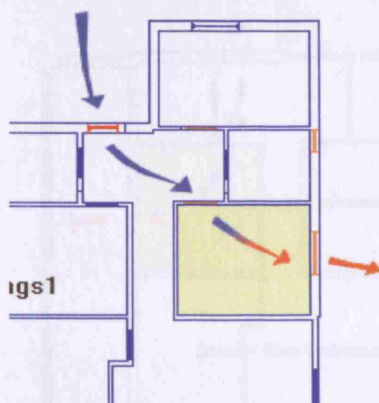


Figure 105: opening opposite windows in room 6

By creating small high openings on the north side facing the corridor in room six, northern wind breezes were captured and sent into the room for cross ventilation. The possible noise that could result from opening the upper window could be resolved by adding noise insulators to the opening. The cross ventilation caused by opening the high window caused the room to cool down and fall into the comfort zone as the graph shows below:

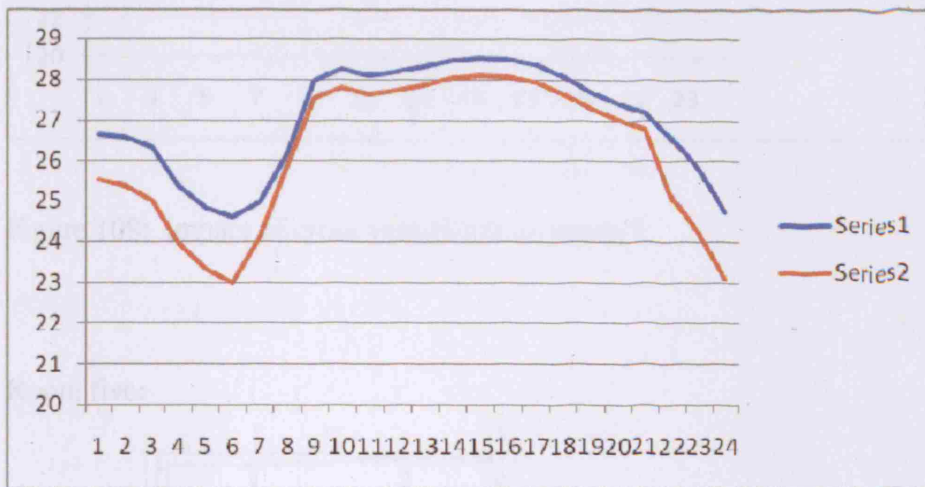


Figure 106: impact of cross ventilation on room 6

The same process was applied to room 7:

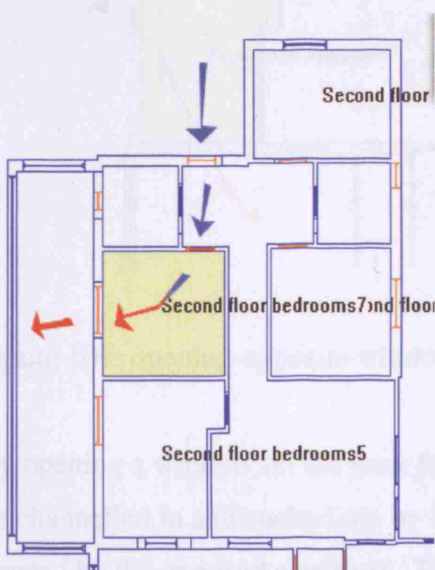


Figure 107: opening opposite windows in room 7

The graph below shows the temperature reduction:

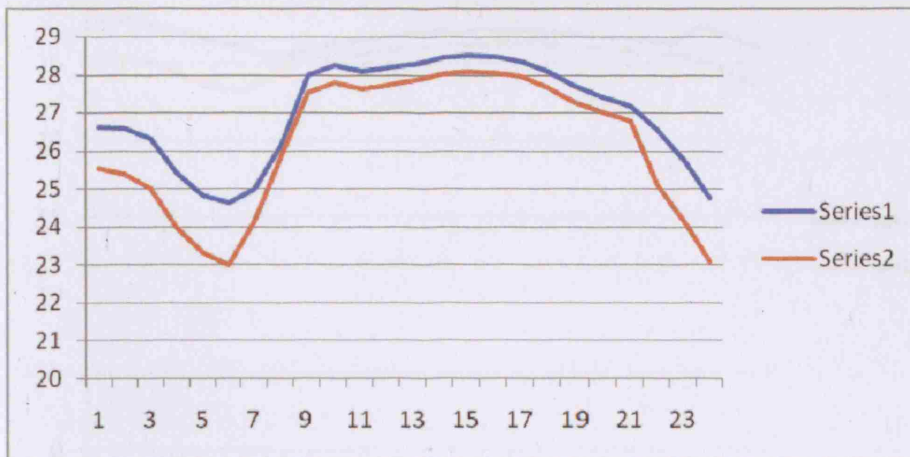


Figure 108: impact of cross ventilation on room 7

Room five:

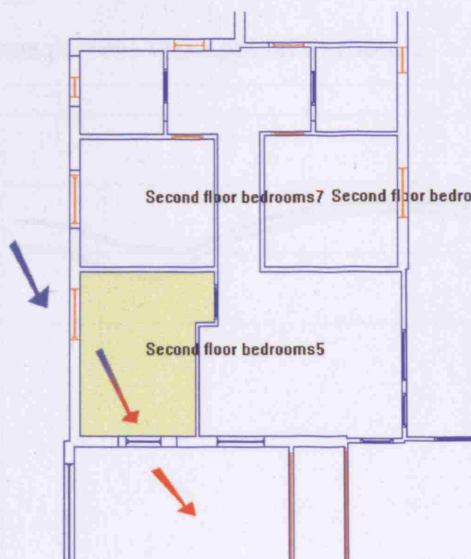


Figure 109: opening opposite windows in room 5

By opening a window on the west facing wall, winds prevailing from the north could be channelled in and sucked out by the pressure difference at the window facing south created by the exposed courtyard. The room temperature was cooled by the air passing through the two openings as shown in the graph below:

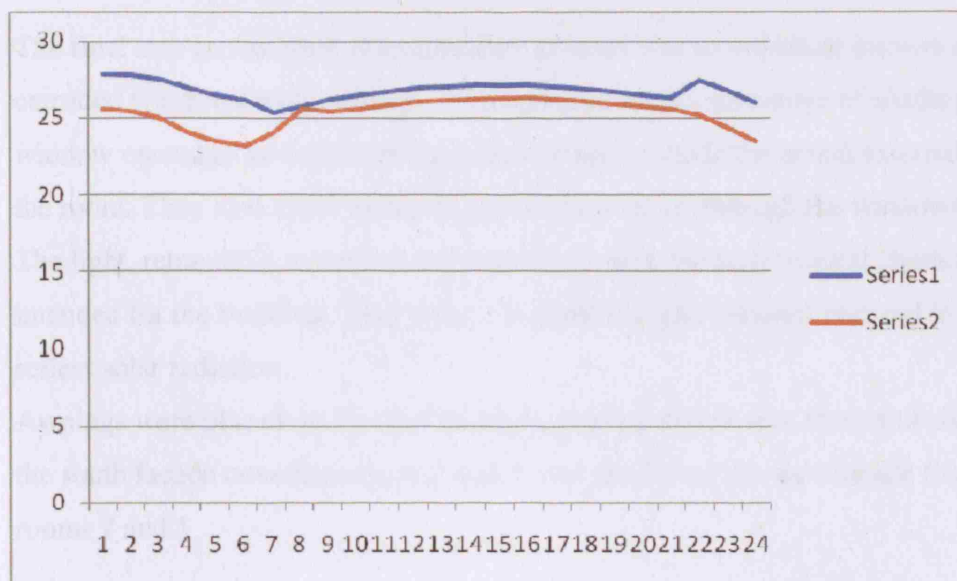


Figure 110: impact of cross ventilation on room 5

Room 2:

The same process was applied to room 2

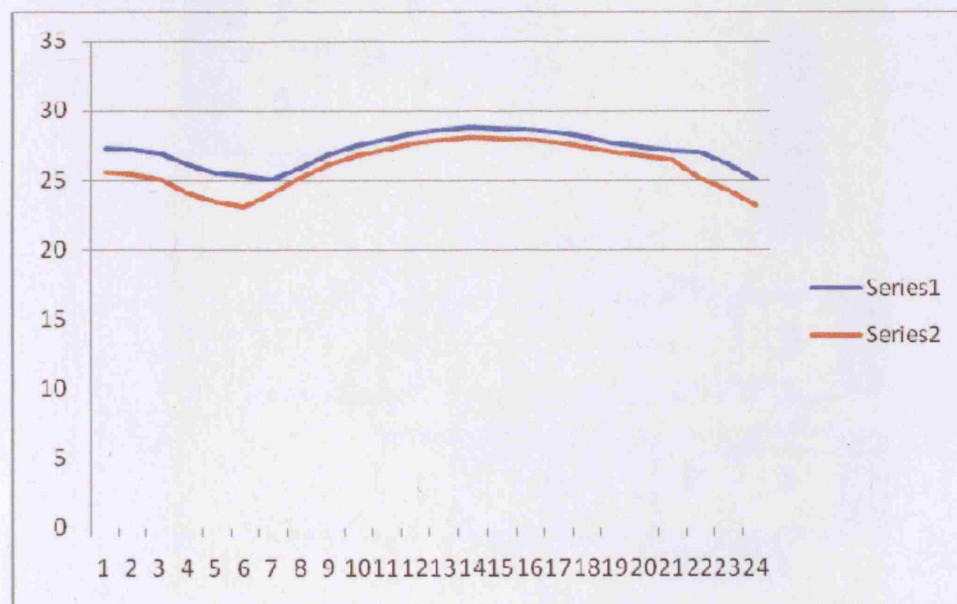


Figure 111: impact of cross ventilation on room 2



### 5.8.10 Awnings

The final step in the internal temperature process was to substitute louvers and extruded windows with awnings. Awnings present the advantage of shading the window openings as well as being wide enough to shade the actual external walls of the room. They also allow an unobstructed flow of air through the windows.

The light, retractable structures don't interfere with the architectural character intended for the building. They were assigned a bright coloured material in T.A.S to reflect solar radiation.

Awnings were placed on the east facades covering rooms one, three and six, and on the south facade covering rooms 2 and 1, and finally on the west facade to cover rooms 7 and 5

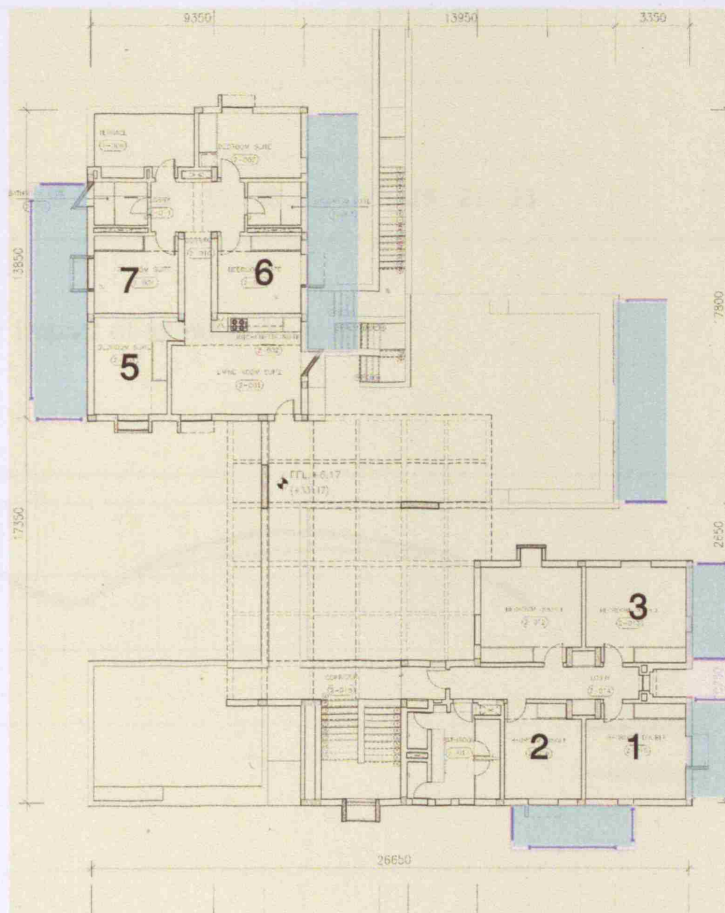


Figure 112: layout showing proposed areas for the installation of awnings

The graphs below present the temperature difference of the rooms after the addition of the awnings:

Room 1:

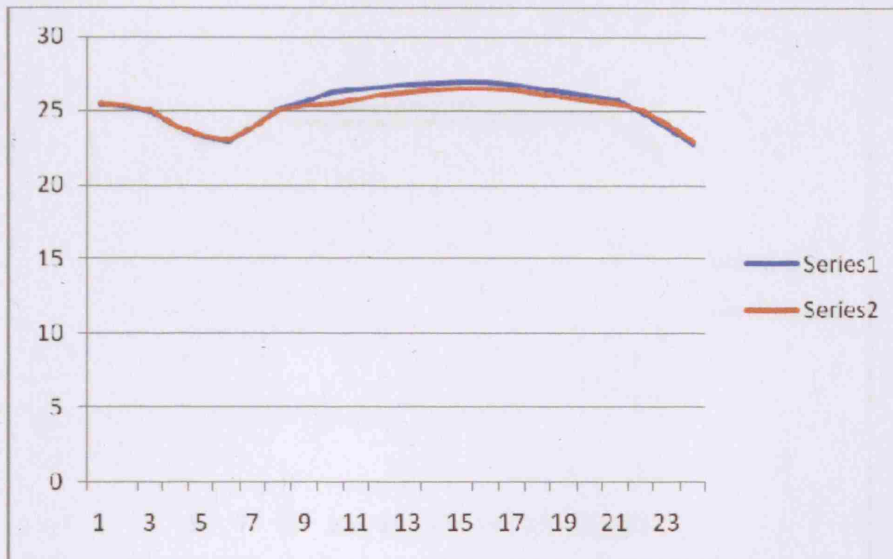


Figure 113: impact of awnings on room 1

Room 2:

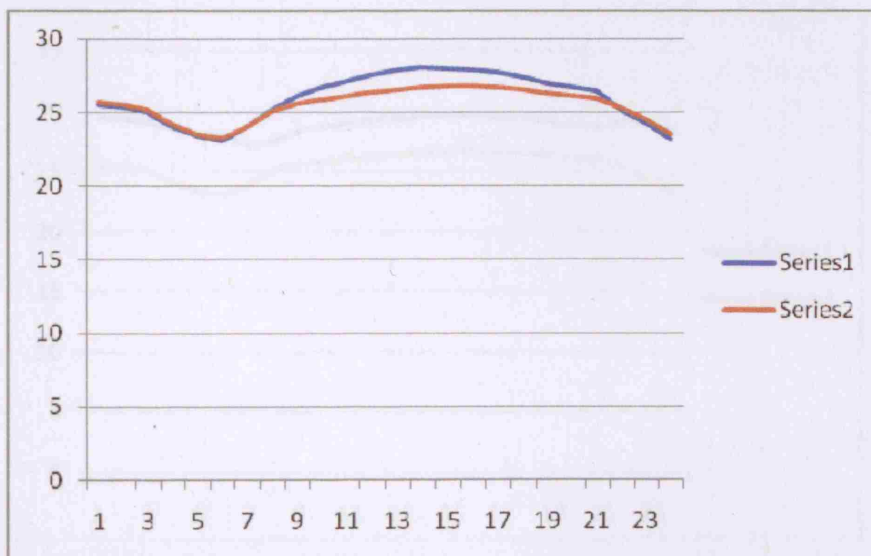


Figure 114: Impact of awnings on room 2

Room 3:

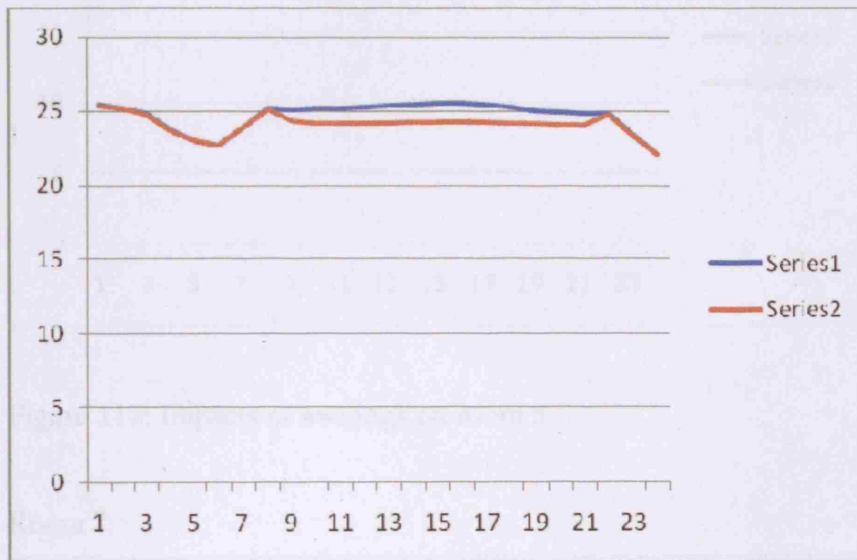


Figure 115: Impact of awnings on room 3

Room 6:

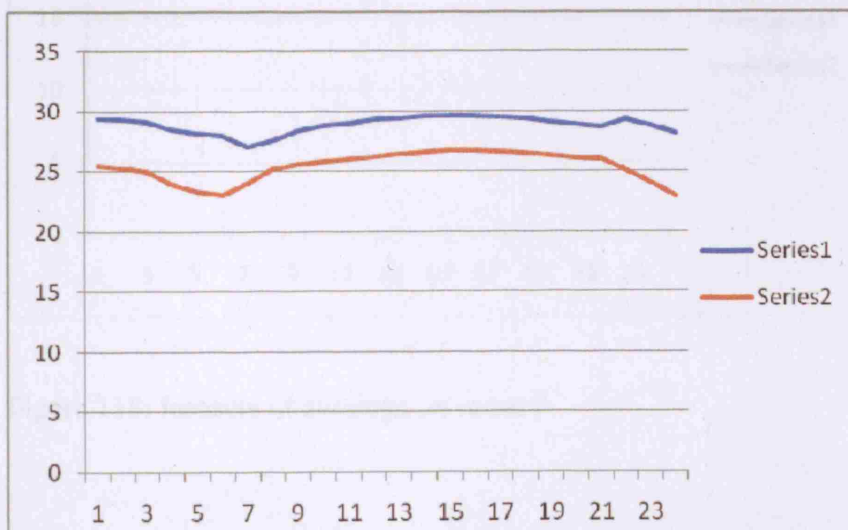


Figure 116: Impacts of awnings on room 6

Room 5:

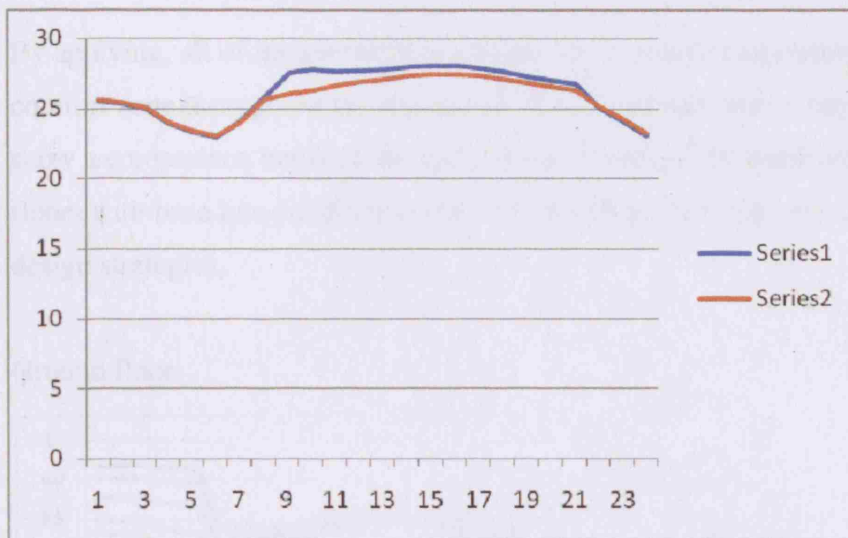


Figure 117: Impacts of awnings on room 5

Room 7:

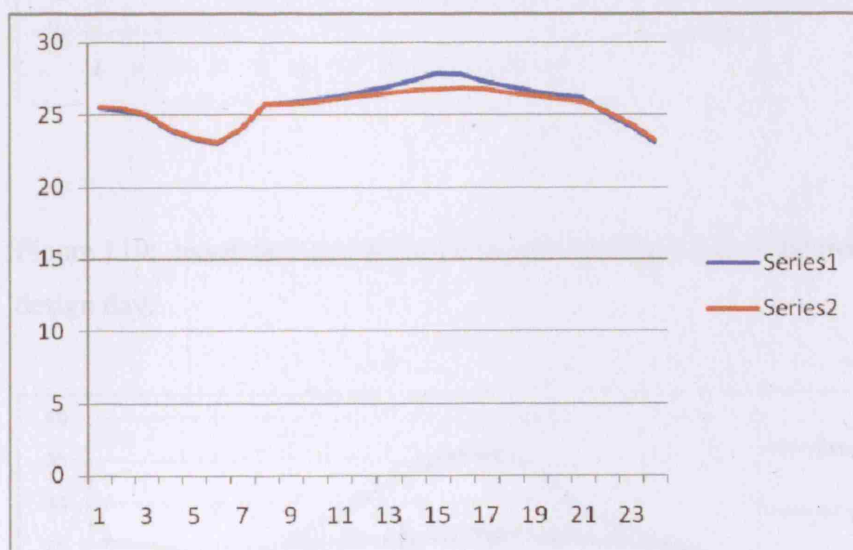


Figure 118: Impacts of awnings on room 7

Results of thermal optimization strategies on internal temperatures during the warmest day of the year:

By applying, all of the previous strategies, the internal temperatures remained in the comfort zone throughout the whole day for the summer design day. The charts below show a comparison between the daily temperatures of the bedrooms on different floors with base line conditions, and the bedrooms after applying the different passive design strategies.

Ground floor:

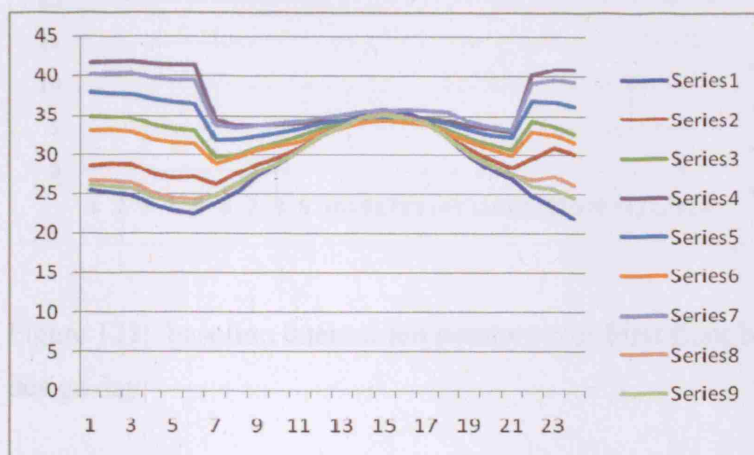


Figure 119: baseline internal temperatures for Ground floor bedrooms during summer design day:

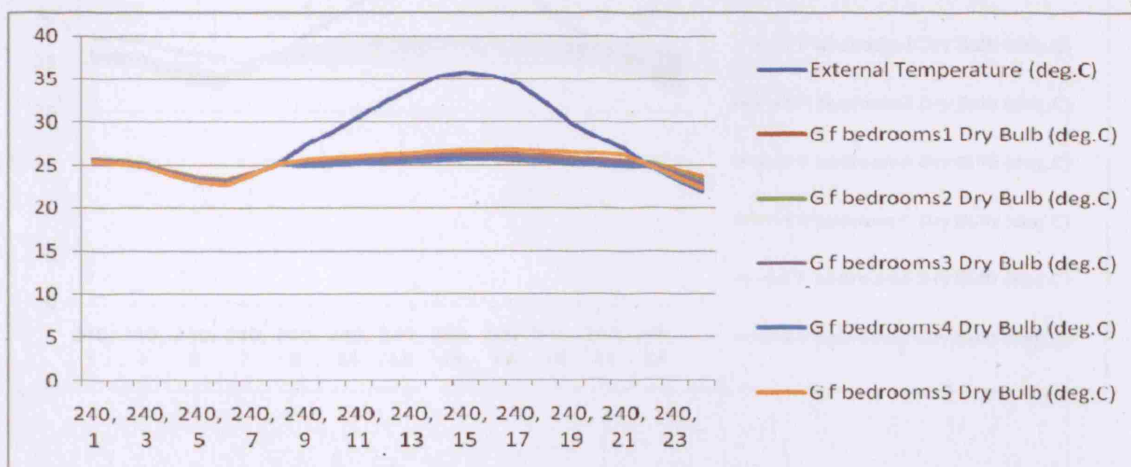




Figure 120: Internal temperatures of ground floor bedrooms during the summer design day after applying passive strategies

First floor:

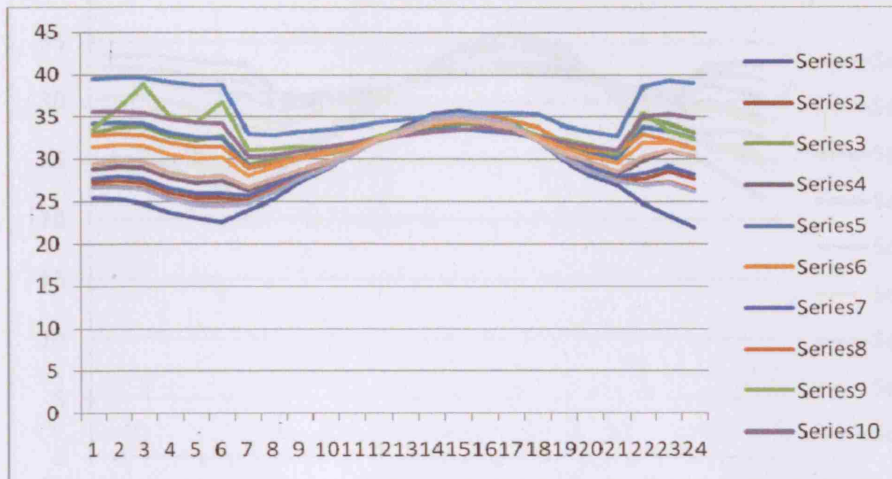


Figure 121: baseline internal temperatures for First floor bedroom during summer design day:

First floor:

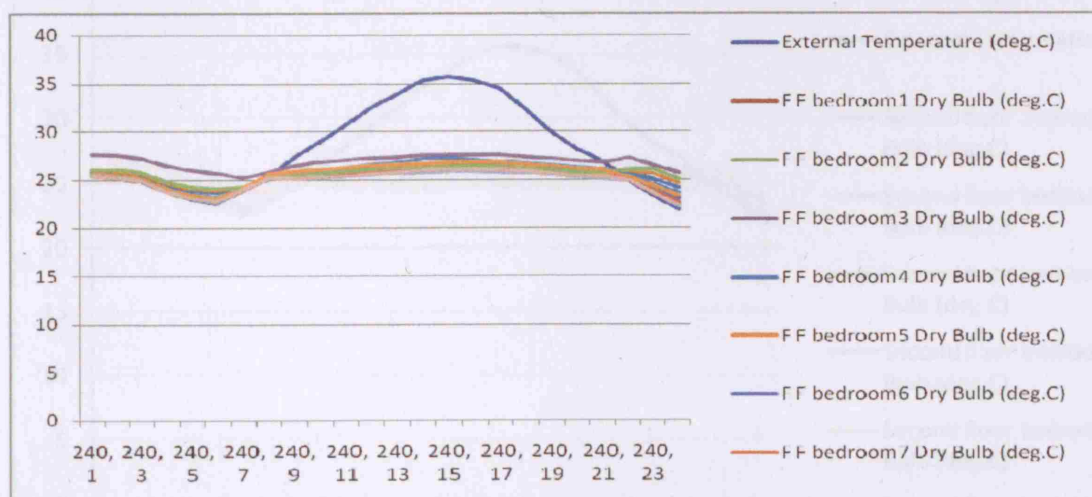


Figure 122: Internal temperatures of first floor bedrooms during the summer design day after applying passive strategies

Second floor:

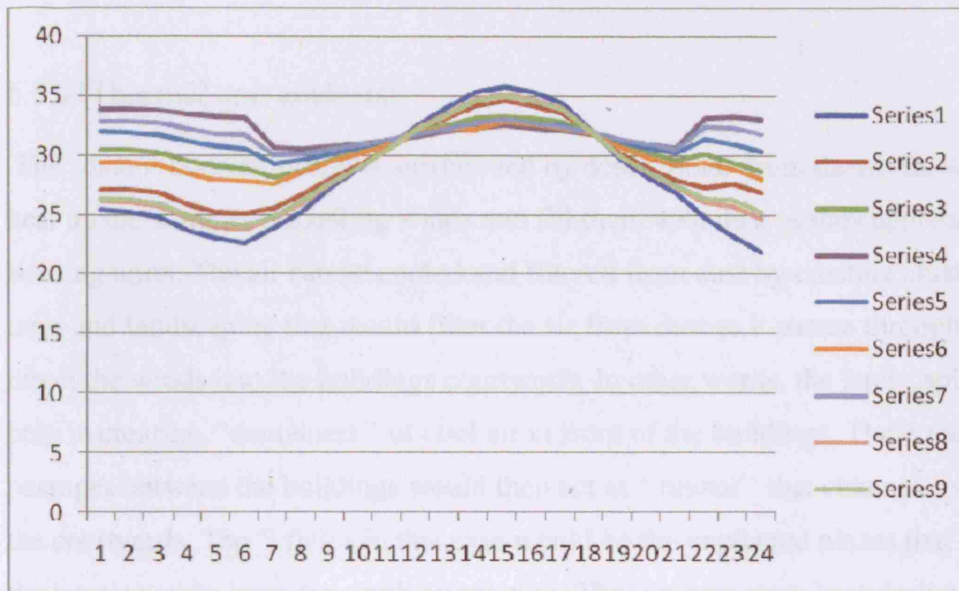


Figure 123: baseline internal temperatures for second floor bedrooms during the summer design day:

Second floor:

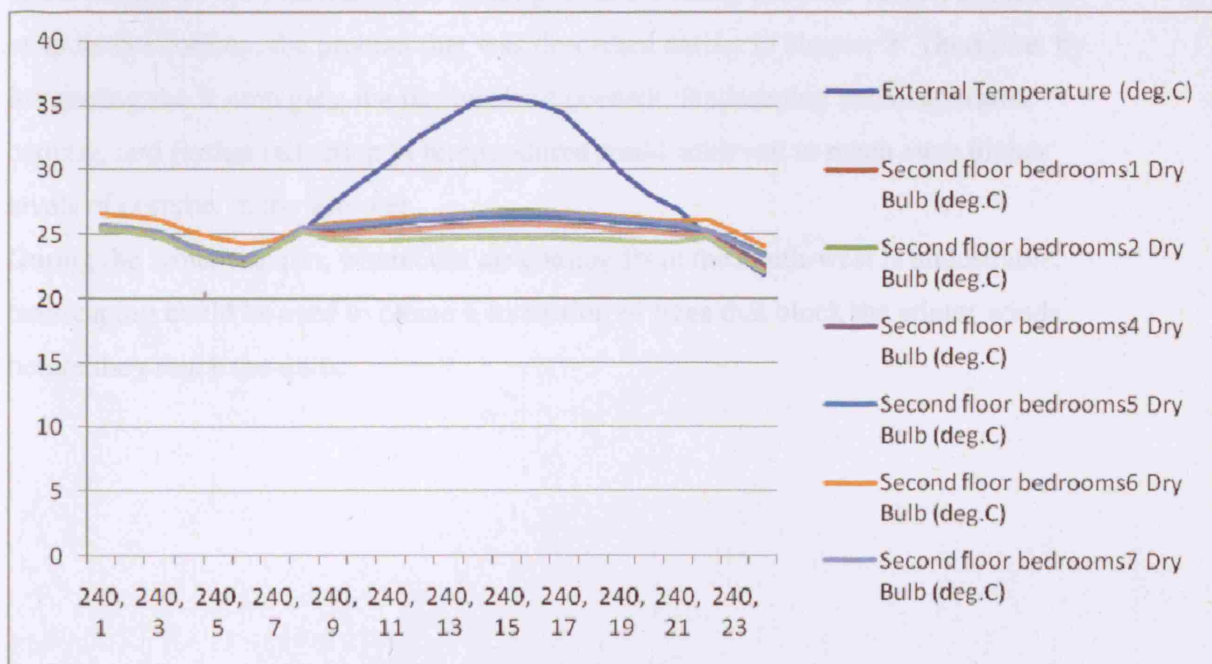


Figure 124: Internal temperatures of the second floor bedrooms throughout during the summer design day after applying passive strategies

#### 5.8.11 Thermal unit analysis:

The student housing parcel is surrounded by desert fields from the north, which could heat up the summer prevailing winds and fill them with dust as they approach the housing units. The air can be cooled and filtered from dust by creating clusters of trees and landscaping that would filter the air from dust as it passes through, and direct the winds into the buildings courtyards. In other words, the landscaping would help in creating “containers” of cool air in front of the buildings. The 4 meter passages between the buildings would then act as “tunnel” that channel cool air into the courtyards. The “” fields in this case would be the unplanted plazas that are facing the housing units from the south orientation. These plazas store heat during mornings which creates a difference in pressure between the fields and the containers, resulting in further suction of the prevailing air from the north to the south. As the air passes from the container to the field, it is directed through the tunnels and the landscaping into the units courtyards to reduce their air temperature. By installing water fountains in the middle of the courtyards, air coming from the fields could be further cooled by evaporative cooling, the process that was described earlier in chapter 2. Therefore, by integrating the 3 strategies, the thermal unit concept, landscaping and evaporative cooling, and further reduction in temperatures could be achieved to reach even higher levels of comfort in the summer.

During the winter season, when cold air coming from the south-west is undesirable, landscaping could be used to create a formation of trees that block the winter winds before they reach the units.

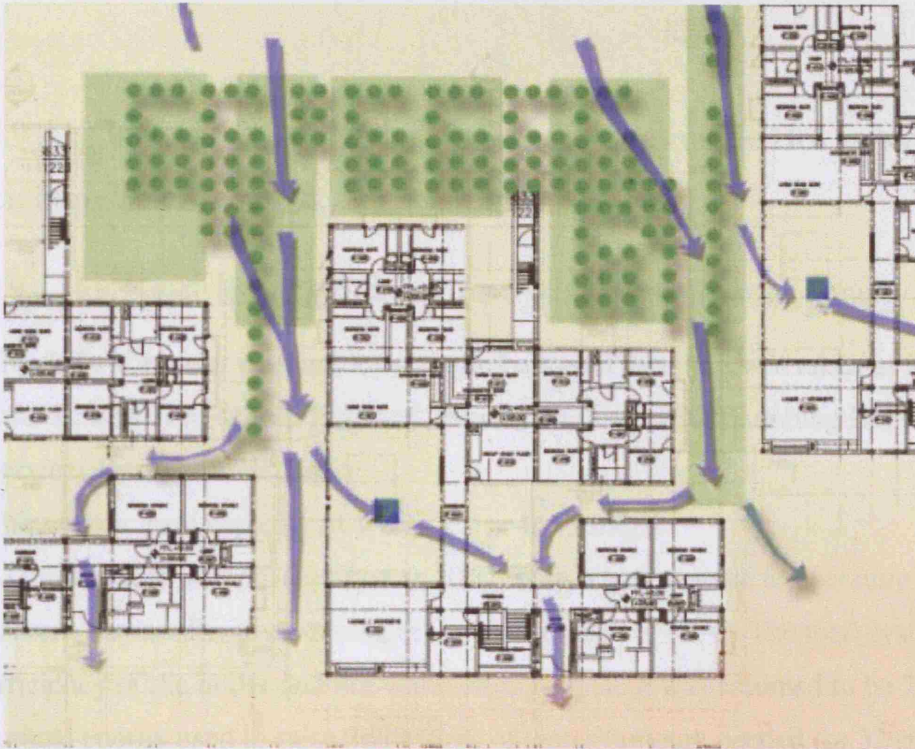


Figure 125: Integration of the thermal unit, landscaping and evaporative cooling strategies

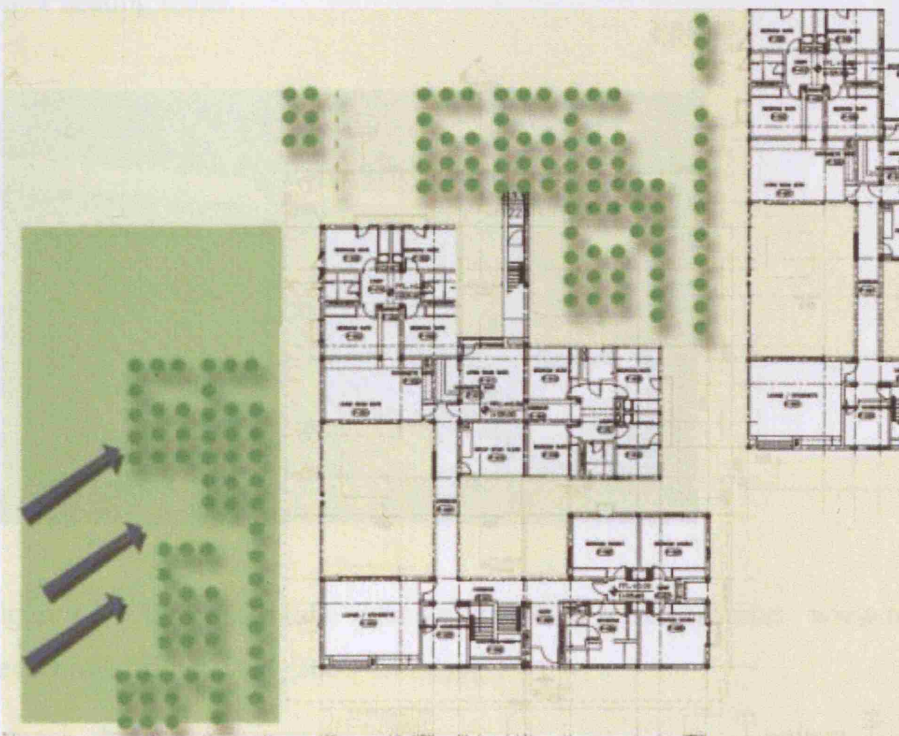


Figure 126: Landscaping strategy for winter



## 5.9 The integration of renewable energies to provide Hot water and Lighting Energy needs:

### 5.9.1 Hot Water Heating (integration of solar water heating panels:

The daily hot water demand for a single bedroom dwelling was taken as 115 litres/day from BSRIA BG14/2003 Rules of Thumb, 2003 and IOP Plumbing Engineering Services Design Guide 2002.

The specific heat capacity of water,  $C_p = 4185 \text{ J/kgK}$

Assume mains water is supplied at  $10^\circ\text{C}$ , with a tank storage temperature of  $60^\circ\text{C}$  to prevent Legionella, gives a temperature difference of  $50^\circ\text{C}$ . The total system efficiency of the boiler and hot water storage system was assumed to be 70%.

Annual energy used to raise 3680 litres of water (amount needed for 32 students) by  $50^\circ\text{C}$  equals to 44.82 MWH.

Evacuated tube solar water heating panel were selected for supplying the required water heating loads.



Figure 127: Evacuated tube solar water heating panels (source: [www.re-nest.com/.../re-nest/4\\_4\\_2008-tubes.jpg](http://www.re-nest.com/.../re-nest/4_4_2008-tubes.jpg) )



By using the ret screen software, it was calculated that 30 collectors with a size of 4m<sup>2</sup>, (roughly a panel needed to fulfil the requirements of one room) spread over an area of 120m was needed to fulfil this requirement.

## Monthly inputs

[Note: 1. Cells in grey are not used for energy calculations; 2. Review this table to check that all required inputs are filled if you change system type or solar collector type or panel type, or method for calculating cold water temperature.]

Month	Fraction of month used (0 - 1)	average daily radiation on horizontal surface (kWh/m <sup>2</sup> /d)	Monthly average temperature (°C)	Monthly average relative humidity (%)	Monthly average wind speed (m/s)	average daily radiation in plane of solar collector
January	1.00	3.29	13.6	59.0	3.8	4.71
February	1.00	4.33	14.9	54.0	4.2	5.53
March	1.00	5.37	16.9	53.0	4.6	6.05
April	1.00	6.43	21.2	47.0	4.5	6.33
May	1.00	7.31	24.5	46.0	4.6	6.59
June	1.00	7.76	27.3	49.0	4.3	6.68
July	1.00	7.53	27.6	58.0	3.7	6.62
August	1.00	7.01	27.4	61.0	3.5	6.68
September	1.00	6.10	26.0	60.0	3.7	6.57
October	1.00	4.96	23.3	60.0	3.8	6.16
November	1.00	3.68	18.9	61.0	3.3	5.19
December	1.00	3.03	15.0	61.0	3.7	4.58

		Annual	Season of Use
Solar radiation (horizontal)	MWh/m <sup>2</sup>	2.04	2.04
Solar radiation (tilted surface)	MWh/m <sup>2</sup>	2.18	2.18
Average temperature	°C	21.4	21.4
Average wind speed	m/s	4.0	4.0

## Water Heating Load Calculation

## Estimate

## Notes/Range

Application type	-	Service hot water	
System configuration	-	With storage	
Building or load type	-	Apartment	
Number of units	Unit	32	
Rate of occupancy	%	20%	50% to 100%
Estimated hot water use (at ~60 °C)	L/d	1,000	
Hot water use	L/d	3,680	
Desired water temperature	°C	50	
Days per week system is used	d	7	1 to 7
Cold water temperature	-	Auto	
Minimum	°C	18.7	1.0 to 10.0
Maximum	°C	23.6	5.0 to 15.0
Months S/W system in use	month	12.00	
Energy demand for months analyzed	MWh	44.82	
	GJ	161.34	

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Solar Resource & Heating Load

Cost Analysis

Table 5: Solar water heating panels ret screen calculation table-1

System Characteristics		Estimate	Notes/Range
Application type		Service hot water (with storage)	
<b>Base Case Water Heating System</b>			
Heating fuel type	-	<b>Electricity</b>	
Water heating system seasonal efficiency	%	70%	50% to 190%
<b>Solar Collector</b>			
Collector type	-	Evacuated	<a href="#">See Technical Note /</a>
Solar water heating collector manufacturer		ABC S.A.	<a href="#">See Product Database</a>
Solar water heating collector model		model XYZ	
Gross area of one collector	m <sup>2</sup>	4.00	1.00 to 5.00
Aperture area of one collector	m <sup>2</sup>	4.00	1.00 to 5.00
Fr (tau alpha) coefficient	-	0.85	0.40 to 0.80
Wind correction for Fr (tau alpha)	s/m	0.040	0.030 to 0.050
Fr UL coefficient	(W/m <sup>2</sup> )/°C	11.56	0.30 to 3.00
Wind correction for Fr UL	(J/m <sup>2</sup> )/°C	4.37	3.00 to 15.00
Suggested number of collectors		6	
Number of collectors		30	
Total gross collector area	m <sup>2</sup>	120.0	
<b>Storage</b>			
Ratio of storage capacity to coll. area	L/m <sup>2</sup>	50.0	37.5 to 100.0
Storage capacity	L	6,000	
<b>Balance of System</b>			
Heat exchanger/antifreeze protection	yes/no	Yes	
Heat exchanger effectiveness	%	100%	50% to 85%
Suggested pipe diameter	mm	N/A	8 to 25 or PVC 35 to 50
Pipe diameter	mm	40	8 to 25 or PVC 35 to 50
Pumping power per collector area	W/m <sup>2</sup>	0	3 to 22, or 0
Piping and solar tank losses	%	1%	1% to 10%
Losses due to snow and/or dirt	%	3%	2% to 10%
Horz. dist. from mech. room to collector	m	5	5 to 20
# of floors from mech. room to collector	-	3	0 to 20
<b>Annual Energy Production (12.00 months analys</b>			
S/WH system capacity		Estimate	Notes/Range
	kW <sub>th</sub>	84	
	MW <sub>th</sub>	0.084	
Pumping energy (electricity)	MW <sub>h</sub>	<b>0.00</b>	
Specific yield	kWh/m <sup>2</sup>	373	
System efficiency	%	17%	
Solar fraction	%	100%	
Renewable energy delivered	MW <sub>h</sub>	<b>44.82</b>	
	GJ	161.35	

[Complete Cost Analysis sheet](#)

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Table 6: Solar water heating panels ret screen calculation table-2

## 5.9.2 Payback period for solar water heating panel's calculation:

It costs **15,400** Egyptian pounds to provide the electricity from the grid to warm up **3680 L** of water annually. The cost of one solar heating panel is roughly 2000 pounds plus installation. The total cost of installing 30 panels is **60,000** Egyptian pounds. It would take 4 years to reach the payback period. After 4 years, the solar water heating panels will provide free heating for the water needs of the student unit.

By using solar water heating panels **22 tonnes/kwh/year** of CO<sub>2</sub> was eliminated.

### 8.9.3 Lighting and electrical equipment loads (integration of P.V cells):

To respond to the estimated annual loads resulting from the lighting and electrical equipment usage for the buildings room, an annual calculation of the loads for each space type was calculated:

lighting and equipment calculations:	
Bedrooms:	
	12
equipment loads:	w/m <sup>2</sup>
lighting loads:	9 w/m <sup>2</sup>
number of hours per day:	4
total number of units:	32
total annual energy consumption:	17490 kwh per year
Kitchens:	
	22
equipment loads:	w/m <sup>2</sup>
lighting loads:	10 w/m <sup>2</sup>
number of hours per day:	1
total number of units:	3
total annual energy consumption:	792 kwh per year
Living rooms:	
	10
equipment loads:	w/m <sup>2</sup>
lighting loads:	10 w/m <sup>2</sup>
number of hours per day:	2
total number of units:	4
total annual energy consumption:	1320 kwh per year



Study rooms:	
equipment loads:	10 w/m2
lighting loads:	10 w/m2
number of hours per day:	2
total number of units:	1
total annual energy consumption:	330 kwh per year
total annual energy consumption:	19932 kwh per year

Table 7: Total annual electricity and electrical appliance energy consumption

As shown from the table, the total annual lighting and electrical equipment loads for the whole building were found to be **19932 kwh per year**

In order to cover the energy requirements of the lighting and electrical equipment loads, Photovoltaic cells were selected to to the high level of solar incidence per m2 provided year round.



Figure 128: Array of Photovoltaics (Source: <http://www.metaefficient.com/images/AP44small.jpg>)

Ret screen was used to size the panels:

System Characteristics		Estimate	Notes/Range
Application type	-	On-grid	
Grid type	-	Central-grid	
PV energy absorption rate	%	100.0%	
<b>PV Array</b>			
PV module type	-	poly-Si	
PV module manufacturer / model #	-	ABC Inc.	<a href="#">See Product Database</a>
Nominal PV module efficiency	%	15.0%	4.0% to 15.0%
NOCT	°C	45	40 to 55
PV temperature coefficient	% / °C	0.40%	0.10% to 0.50%
Miscellaneous PV array losses	%	10.0%	0.0% to 20.0%
Nominal PV array power	kWp	1.80	
PV array area	m <sup>2</sup>	12.0	
<b>Power Conditioning</b>			
Average inverter efficiency	%	80%	80% to 95%
Suggested inverter (DC to AC) capacity	kW (AC)	1.4	
Inverter capacity	kW (AC)	72.0	
Miscellaneous power conditioning losses	%	0%	0% to 10%
<b>Annual Energy Production (12.00 months analysed)</b>		<b>Estimate</b>	<b>Notes/Range</b>
Specific yield	kWh/m <sup>2</sup>	148.2	
Overall PV system efficiency	%	9.9%	
PV system capacity factor	%	11.3%	
Renewable energy collected	MWh	2.222	
Renewable energy delivered	MWh	1.778	
	kWh	1,778	
Excess RE available	MWh	0.000	
<a href="#">Complete Cost Analysis sheet</a>			
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Table 8: Table 9: P.V cells ret screen calculation table 1

As shown from the ret screen table, 12m of photovoltaic cells were needed to produce 1778 kwh per year. Therefore, by applying cross multiplication; **134m<sup>2</sup>** are needed to cover the annual energy consumption from lighting and electrical equipment consumption.



#### 8.9.4 Payback period for Photovoltaic cells calculation

The cost of installing **74m<sup>2</sup>** of P.V panels is approximately **90,000** Egyptian pounds.

The annual electricity grid cost is 9,000 Egyptian pounds. . Simple payback is therefore **10 years**.

By installing P.V cells, 9 tonnes/kwh/year was eliminated.

The costs of installing p .v panels and solar water heating panels could be accommodated from a percentage of the annual accommodation fees of the students.

#### 8.9.5 Installing the panels on the building

In total, **240 m<sup>2</sup>** are needed for both the solar water heating panels and the P.V cells.

There are two options to accommodate the cells. The first option is to use a combination of roof space and the area of the shading slab. The second option would be to cover parts of the roof as well as the external courtyard. In the second option, the P.V's would work as a shading element as well as an energy generating cell.

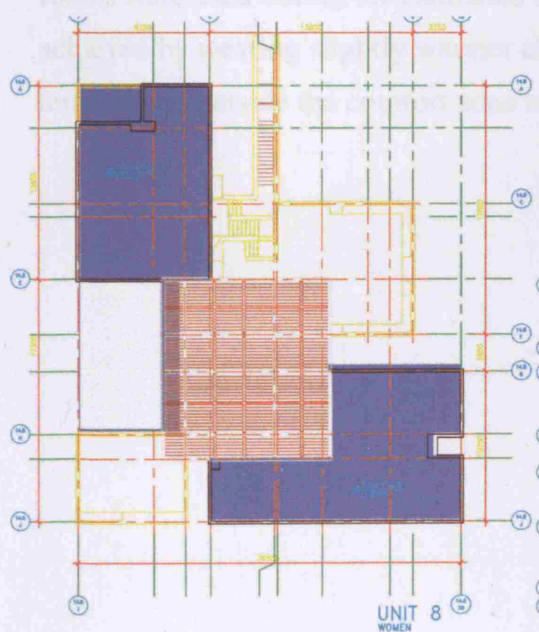


Figure 129: option 1: using the shading slab and the roof to install panels

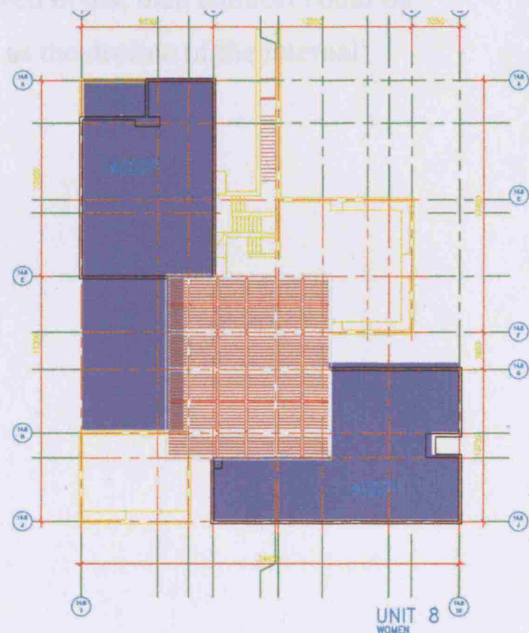


Figure 130: option 1: using the roof with the external courtyard Cover to install panels

## 5.10 Summary of the results

By applying different passive strategies, the study showed that the building could operate without incorporating any mechanical heating or cooling.

The charts below present a comparison of the initial buildings internal Temperatures and the final modified version proposed for some of the summer and winter season s months for the bedrooms in different floors:

As explained previously in chapter 4, the targeted thermal comfort zone ranges from 20 deg.c to 28 deg.c in Cairo approximately. The comfort zone is highlighted in yellow in the following charts to clarify the percentage of time that the temperatures fall within its range.

### 5.10.1 Summer and winter seasons overall temperatures

By optimizing internal temperatures during the warmest and coldest days of the year, the internal temperatures stabilized within the comfort zone during the occupied hours for the whole year. During winter, internal temperatures were allowed to decrease slightly below the comfort zone during unoccupied hours, if, as an exception, the rooms were used during the estimated unoccupied hours, then comfort could be achieved by wearing slightly warmer clothing, as the decline of the internal temperature outside the comfort zone is slight.

Summer season:

Ground floor bedrooms:

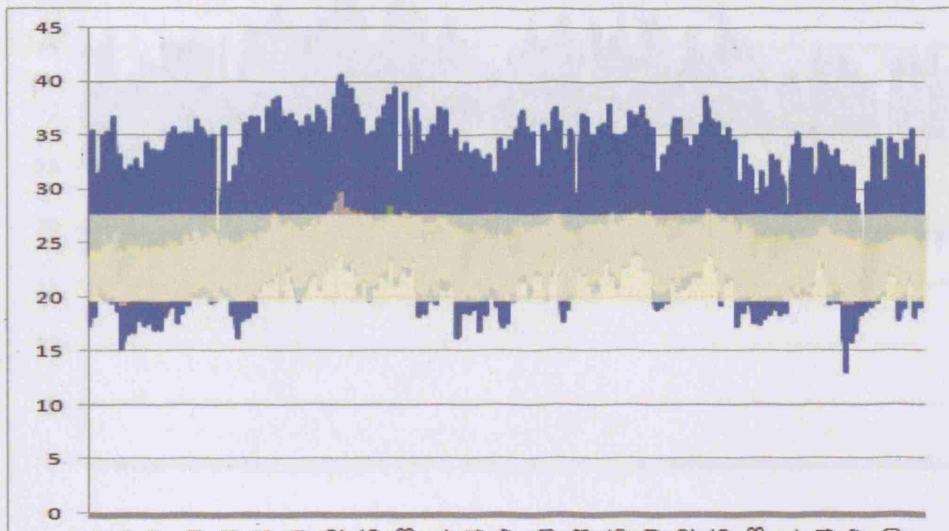


Figure 131: Internal temperatures of the ground floor throughout the summer season

First floor bedrooms:

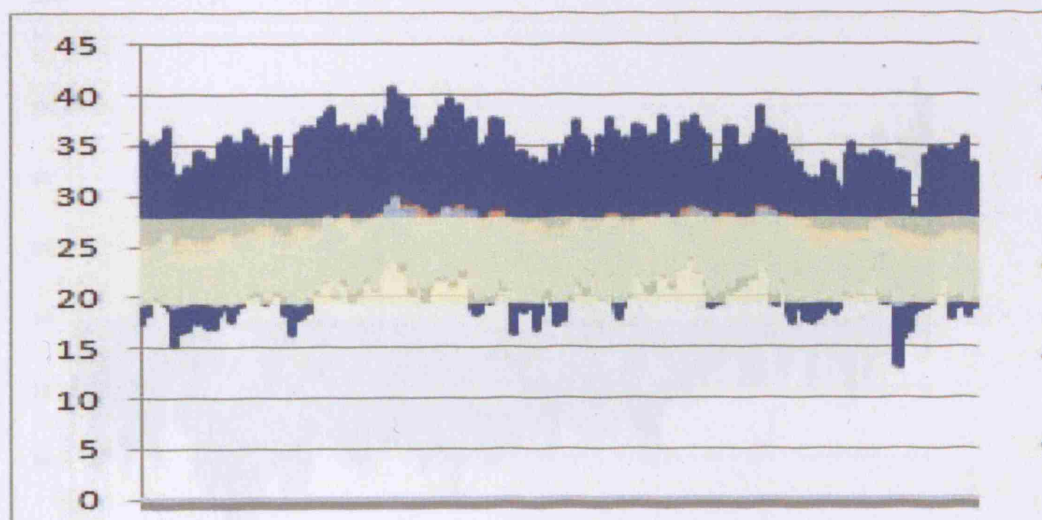


Figure 132: Internal temperatures of the first floor throughout the summer season

Second floor bedrooms:

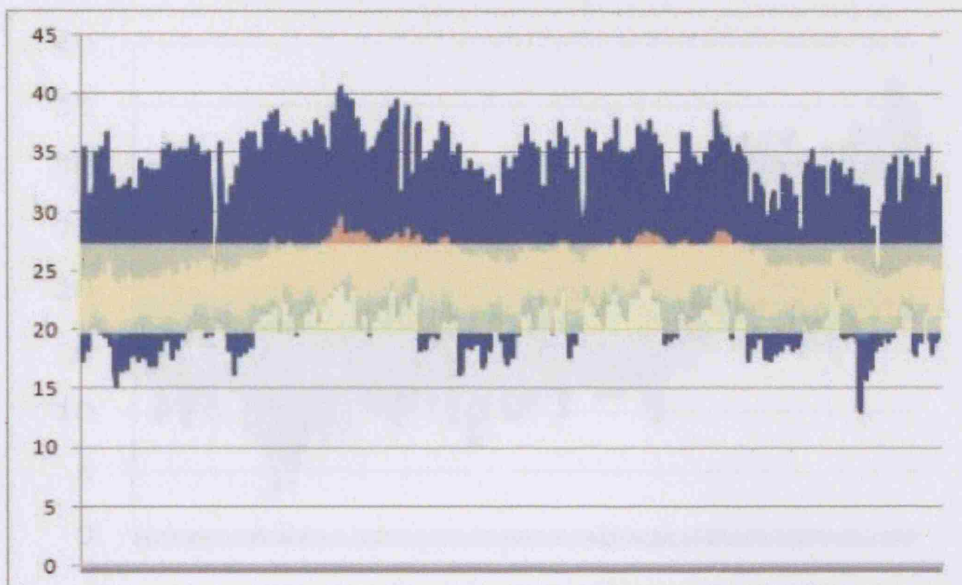


Figure 133: Internal temperatures of the second floor throughout the summer season

Winter season:

Ground floor bedrooms:

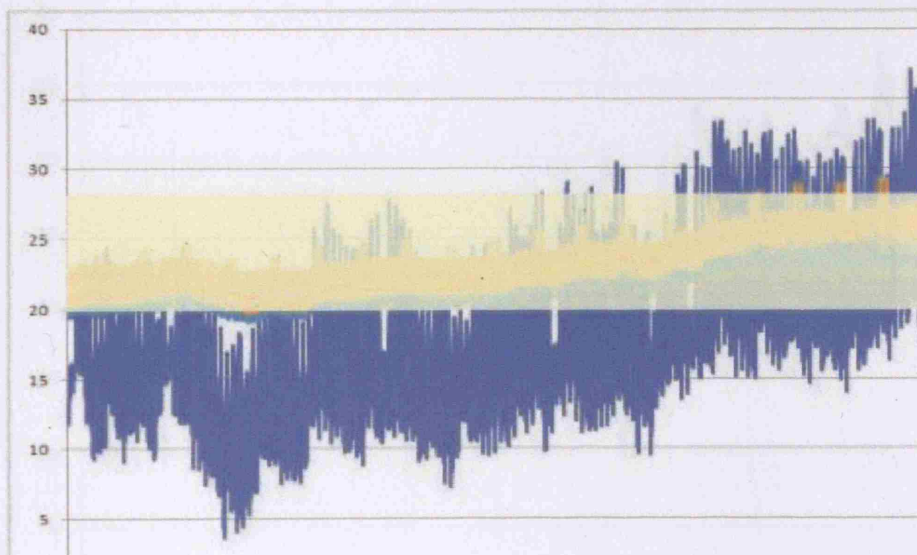


Figure 134: Internal temperatures of the ground floor throughout the winter season



First floor bedrooms:

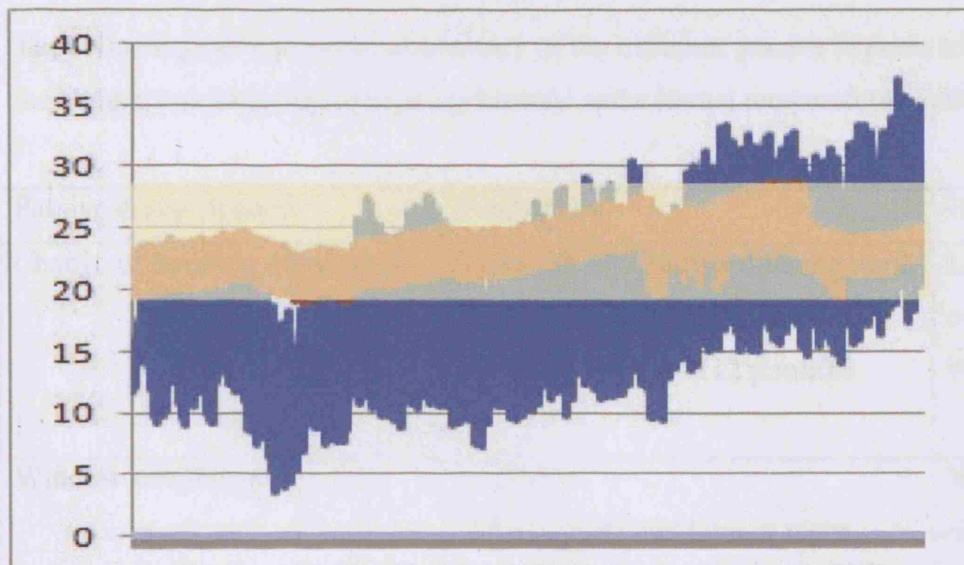


Figure 135: Internal temperatures of the First floor throughout the winter season

Second floor bedrooms:

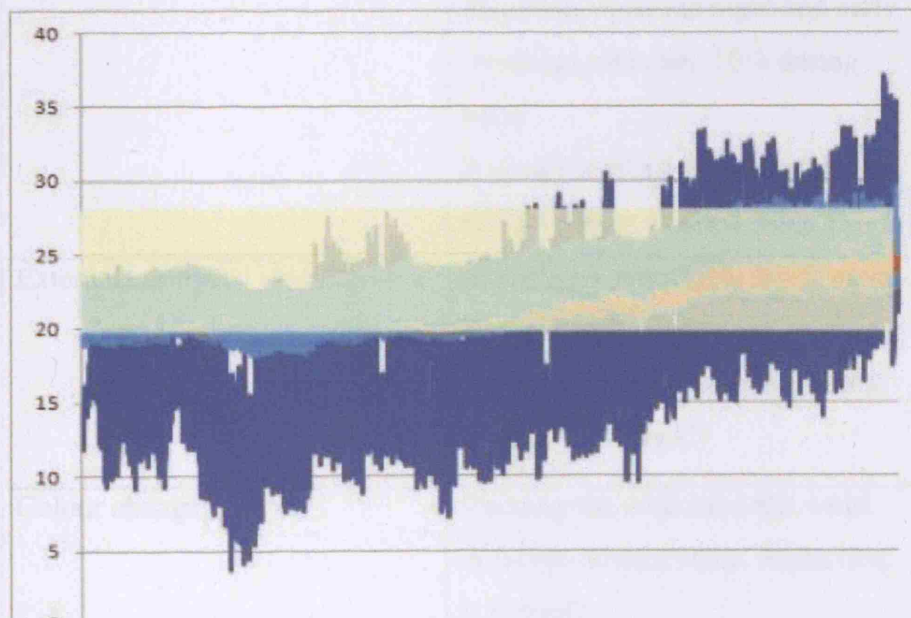


Figure 136: Internal temperatures of the second floor throughout the winter season



### 5.10.2 Summary of results table

The following table presents a summary of the different passive features tested and their impact on reducing/increasing internal and external temperatures in the building:

Passive design feature	Best option	Base case
Change of building orientation	Long side of Courtyard facing north Reduction during peak hour in external courtyard (12.p.m):0.8 deg.C	Long side of courtyard facing west
Window schedules	Summer: Opening the windows at night, with closed windows during noon hour's average temp. Internal temp Drop during peak hours during summer design week: 5.1 deg.C Winter: Windows closed at night and early mornings and open 10% during noon. Average internal heat gains during design winter week: 4.3 deg.C	Windows always open 40% of the whole time.
External courtyard shading	Installing a retractable fabric cover that provides shading Maximum temp. drop in external courtyard: 4 deg.C	Open courtyard, Exposed to direct solar radiation
Colour change	Painting the external walls white Average internal temp. Reduction: 0.5 deg.C	Brownish-Red paint
Wall insulation	Adding 55mm of insulation to the 50 mm cavity U-value = 0.5 w/m <sup>2</sup> C	Double brick layers with 50 mm cavity in between

	Average internal temp. Drop: 0.3 deg.C	U-value: 1.48 w/m <sup>2</sup> C
Material change of external walls	Adding stone cladding U-value = 0.2 w/m <sup>2</sup> C Average temp. drop: 1 deg.C Max. Temp drop during peak hour: 2 deg.C	Plaster brownish-red paint. U-value = 1.48 w/m <sup>2</sup> C
Floor Insulation	Adding of insulation U-value = 0.14 w/m <sup>2</sup> C Average internal temp. Drop during summer design week: 0.2deg.C	Uninsulated floor slab 150mm U-value= 1.47 w/m <sup>2</sup> C
Roof insulation	Planting the roof U-value = 0.17 w/m <sup>2</sup> C Average internal temp. Drop during summer design week: 0.5 deg.C	8 material layers: 1-tiles 2-Sand and mortar bed 50mm 3-separation layer 0.5mm 4-Extruded polystyrene 50mm 5- Cement screed 30 mm 6-Waterproofing membrane 4mm 7-light weight concrete 8-R.C structural slab. U-value= 0.35 w/m <sup>2</sup> C
Glazing	Double glazing with argon filling and low-e external coating U-value = 1.1 w/m <sup>2</sup> C	Single glass pane U-value = 5.7 w/m <sup>2</sup> C

	Average internal temp. Drop during summer design week: 1 deg.C Average internal temp. Gain during Winter design week: 2.2 deg.C :	
Cross ventilation	The addition and sizing of an extra window opposite to the existing one. Average internal temp. Drop during Winter design week: 2 deg.C	Some rooms have only one window opening
Installation of awnings	Installation of light coloured retractable awnings	Extruded windows, tilted windows and horizontal and vertical fins

Table 10: Table 11: Summary of results table

### 5.10.3 Results comments and interpretations

Analysing the results, providing a responsive window schedule to the external temperatures, adding wall cladding and shading the external courtyards were found to be the most effective temperature optimization measures.

Never the less, the integration of all of the temperature optimization measures examined will lead to the best overall results. The following section provides interpretations on all of the measures examined.

#### 5.10.3.1 Occupancy schedules and internal gains of internal spaces:

Occupants, lighting and equipments in rooms are sources of heat. When sizing the annual energy consumption from the air conditioning of a building, it is crucial to take into account two important factors: the expected occupation schedule for the internal spaces and the internal gains resulting from the occupants, lighting and equipments in rooms. As shown from the study, the heat gains resulting from the room's occupants,

lighting and equipment, coupled with a window schedule that is responsive to the external temperature, could cause major reductions of the annual heating load of the buildings without the use of any mechanical heating. A common mistake made when estimating the cooling/heating gains of a building is not taking into account the actual time that the spaces will be occupied, hence inaccurate sizing the mechanical air-conditioning equipments. This is especially important for student housing buildings, which has an occupancy pattern that is close to that of a hotel, i.e., the occupants are outside of their rooms for a large percentage of the time, either attending classes or going away for vacation in the summer.

#### 5.10.3.2 Orientation:

The simulations showed that by orienting the exposed courtyard to the north, a temperature reduction of 0.8 deg.C is possible. Placing the courtyard in a position where the exposed side facing the northern winds and its other built sides covering it from the intense midday sun provides a good base for addition of other temperature reduction strategies.

#### 5.10.3.3 Massing:

In hot-dry climates it is preferable to position the buildings of a cluster closely to each other to benefit from the shading of the buildings on each other and to produce externally shaded pathways and interaction spaces. The current layout of the units could be improved to provide effective shading from both sides of the building. Attention has to be given to leave enough space so as not to obstruct desirable solar gains in the winter.

#### 5.10.3.4 Window schedules:

By assigning a summer window schedule that closed during midday peak external temperatures and opened during night time, internal temperatures were reduced for the whole day.

Closing windows when the external temperatures were too high to provide any cooling helped in reducing internal temperatures during peak hours, while opening windows during night time allowed the cool night air to enter and cool down the

thermal mass of the ceiling that absorbed heat during midday, thus reducing internal temperatures at night and making the space cool for the next morning.

During the winter, heat resulting from occupants, light and electrical equipments was maintained in internal spaces by closing the windows and only leaving a small fraction open for sufficient ventilation rates.

#### 5.10.3.5 Courtyard retractable tensile cover:

By adding a retractable fabric cover over the exposed courtyard, the temperature dropped by 4.deg.C during peak hours, providing comfortable temperature conditions for occupants and contributing in internal temperature reductions of surrounding rooms. Coupled with the integration of a water fountain to provide evaporative cooling, the courtyard could provide an additional pleasant outdoor space for the buildings occupants and a cool air container that contributes to reduced internal Temperatures for all of the adjacent rooms.

#### 5.10.3.6 Landscaping:

If the environmental optimization strategy is partially dependant of landscaping and vegetation, it is important to start planting the trees at an early stage in the project, even before the actual construction of the buildings to avoid additional cooling/heating loads that could occur while the plants are still growing.

#### 5.10.3.7 Insulation, external wall material and colour change:

Applying different thickness of insulation to the external wall resulted in minimal internal temperature reductions, basically due to the fact that the wall had two layers of brick with a 50 mm cavity in between to start with. Planting the roof lowered its u-value, resulting in half a degree of reduction, as the roof is the most exposed surface to direct solar radiation. Insulating the floor slabs did not contribute to significant temperature reduction, as the internal temperatures in different floors are very similar.



#### 5.10.3.8 Glazing

The single glazed panes that are currently installed presented thermal bridges that allowed significant heat transmission from the inside of the building to the outside and vice versa.

By replacing the single glazed window units with double glazed panes with argon filling and low-e coating, the building envelope was able to longer maintain cool internal conditions in the summer and warmth during the winter.

#### 5.10.3.9 Cross ventilation:

The courtyard building type of the unit provides a good base for cross ventilation, as most of the rooms had two exposed sides. By opening up an additional window on the adjacent side of the room and providing the right window sizing that further promotes wind passage, temperature reductions were achieved that reached 2 deg.C in some rooms during peak hours.

#### 5.10.3.10 Shading:

The use of existing tilted and straight extruded frame window openings can be an effective means to limit direct solar gains, but they largely limit the penetration of air and natural daylight. If these elements have to be used for architectural character purposes, then appropriate orientation has to be considered as well as appropriate window sizing for maximum air penetration.

Even though the existing horizontal and vertical fins on the south and west facades were sufficient to block the intense summer sun from entering through window openings, more internal temperature reductions were proved possible with retractable awnings that covered the whole facade, including the window openings. When retracted, the awnings allowed for maximum desirable solar penetration in the winter.

## CHAPTER.6: DISCUSSION

## 6. Discussion

### 6.1 Why isn't energy efficient design widely practiced?

Reviewing the results that demonstrate the effectiveness of applying passive temperature and energy optimization features to the building design, it would be expected that it is widely practiced in contemporary urban development, but in reality it is seldom applied in Egypt. This is due to a number of factors:

#### 6.1.1 Lack of the application of a strict energy efficient building code:

One of the main factors that hindered the application of energy efficient design in buildings in Egypt was the lack of enforcing regulation.

In the past, Egypt had no energy efficiency standards for building construction.

Although individual initiatives by architects to produce 'green' buildings, these efforts have not succeeded in changing overall design practices in Egypt towards improved energy efficiency.

Currently, Egypt is on its way to enforce energy efficiency in buildings through a new revised building code for residential and commercial buildings. Governmental organisations were established to be responsible for energy planning and efficient utilization, information dissemination and capacity building as well as devising the necessary codes and standards.

Details of these codes and their aims are reviewed in depth in the appendix.

(Appendix)

#### 6.1.2 Limited integration of renewable energy sources:

The limited integration of renewable energies in the building sector in the past was basically due to the following reasons:

- Limited access to international markets for modern Renewable energy technologies (R.E.T) .
- Limited involvement of the private sector
- High subsidy of fossil fuel limits the competitiveness of renewable.
- Lack of incentives for using renewable energy technologies such as tax cut, etc.
- Limited R&D, demonstration and implementation projects.
- Lack of awareness/access to information on RETs.

- Customs on RE systems and components.
- Technical Lack of access to the technology/know how,
- Very little funds are available to promote R&D in RE Technologies and invest in RE Components manufacturing and Human resources training.

#### 6.1.3 Living an energy inefficient life style is regarded as a symbol of status.

Welfare concept has been rapidly evolving. As well as clothes mean much more than the need for thermal protection (and then we evolve towards the concept of fashion), housing means more than the need for a comfortable place to live. As that symbol, it must adapt to the established standards of status. Energy saving and taking advantage of the sun may not fit these standards, but having an expensive conditioning system to overheat in winter and overcool in summer every single space in the house (even if it is seldom used) may do. The Media is emphasising this concept, especially campaigns for conditioning manufacturers and the consumer, with no information on the topic, cannot demand alternative products he/she does not know.

#### 6.1.4 Direct imitation and influence of western building designs

Another factor that contributed to less interest in general for applying climatically responsive buildings is the Influence of westernization and trying to copy building types that are not compatible to use In Egypt's hot climate, such as the emergence the glass box office building types which have proved to be energy inefficient and generally produce uncomfortable working spaces for their inhabitants. These designs which are completely disregarding local climatic conditions have Resulted in many substandard houses, where heating and cooling are a prerequisite to achieve thermal comfort.

'unaware that civilization is measured by what one contributes to culture, not by what one takes from others, he (the local architect) continues to draw upon the works of western architects in Europe and North America, without assessing the value of his own heritage. (Hassan Fathy)

What appears to be needed is a structured national strategy that involves the combined participation of individuals, companies, building codes and regulation implementation, research institutes, industries, NGO's and the government. The section below lists a number of proposed components of this strategy.

## 6.2 Guidelines for proposed energy efficiency strategy for the building sector

- Increasing awareness on bioclimatic design & energy saving. Governments have to promote research on the topic and generate new legislation and standards. For example, something as simple as good insulation in buildings to keep coolth heat inside is a topic for legislation of increasing importance. In a lot of countries institutions are appearing which perform research and spread bioclimatic knowledge among architects and builders (like CIEMAT in Spain).
- Increasing the awareness of the local desert inhabitants of energy efficient practices and encouraging them to participate in building their own built environment. Better understanding of climatic design generates the impetus to integrate it into any future design.
- Conducting more local research on the topic and assigning more research budgets for investigating new methods of energy saving and material recycling.
- Participation in more international projects that involve technology transfer, such as a recent collaboration with the Japanese and Danish governments on 2 wind farms with a capacity of 120 mw in Zafarana region on the Suez gulf coast.
- The promotion and financing of the application of renewable energy sources and the reuse and recycling of materials for construction. More investments from both the public & private sector are needed.
- Demonstrations of systems, brochures, training courses, and workshops for targeted users. These programs should be prepared based on market surveys and studies. It is



proposed that the programs should concentrate on use of media especially TV and newspapers.

Lastly, it is important to closely examine old, traditional passive design methods and when needed to make conscious modifications to it.

The success of these traditional, cheap methods of construction for adapting and responding to the local climate should not be abandoned, as they grew out of countless trails and accidents from generations of builders who simply continued to use what worked and discarded what didn't.

What needs to be done is an appraisal of the conditions under which the traditional solutions are technically, environmentally, socially, and economically valid and bridge the gap of integrating them

With contemporary technology, based design approaches today.

“Modern science can develop human capabilities to use natural sources of energy far beyond what has been achieved in vernacular architecture. If science and technology are to revitalize

Architecture through a systematic and comprehensive comparison of new and traditional structures, the principles that produced the solutions must be respected.

This is the only way we can surpass in human and ecological quality the achievements of traditional architecture in the hot arid regions of the world. Such an effort can only enrich human thought and culture. “(Hassan Fathy)

## CHAPTER.7: CONCLUSION

By applying the above measures, the temperature of the courtyard is reduced by 4.5 deg.C.

The temperature of the courtyard is reduced by 4.5 deg.C, which is relative to the internal temperature of the room.

The temperature of the courtyard is reduced by 4.5 deg.C.

Installing a retractable light awning structure to cover the wall & external courtyard

during the summer, which reduces the courtyard temperature by a maximum of 4.5

deg.C during the peak hours (12 p.m.).

Applying a window treatment that allows light to enter the courtyard

during the summer, which reduces the courtyard temperature by a maximum of 4.5

deg.C during the peak hours (12 p.m.).

Changing the color of the external wall from dark to light, resulting in an

internal temperature reduction of 0.5 deg.C.

Applying the external wall type to reduce the temperature of the

external wall and reduce the temperature of the courtyard by a maximum of 4.5

deg.C during the peak hours.

## 7. Conclusion

The energy and co2 reductions achieved by applying passive design strategies and integrating renewable energies provide an example of the reductions possible by applying more energy efficient design practices to future built environments.

The T.A.S simulations show that an annual energy saving of **31046 kwh** could be achieved as well as temperature optimization and thermal comfort by applying the following measures:

- operating the building on mixed mode, where passive cooling is integrated with air conditioning , which reduced the loads from air conditioning to **8241 KWH/year**.
- Shading the unit from surrounding buildings, which reduced the Temperatures in adjacent rooms by a maximum of 2.5 deg.C during midday.
- changing the orientation of the building, which results in a decrease in temperature of the external court yard of 0.8 deg.C, which in return reduces the internal Temperatures of the rooms adjacent to the courtyard.
- Installing a retractable light tensile structure to cover the unit's external courtyard during the summer, which reduced the courtyards Temperatures by a maximum of 4 deg.C during the peak hour (12 p.m .)
- Applying a window schedule that allows night ventilation in the summer. Night ventilation contributed in bringing down the internal temperatures of the room to approximately 5 deg.C from the external temperature during midday peak hours.
- Changing the colour of the external wall from dark red to white, resulting in an internal temperature reduction of 0.5deg.C
- modifying the current external wall type to include a 50 mm insulation to the existing cavity and adding stone cladding, which reduces the internal temperature by approximately 2.2 deg.C.

- applying floor slab and roof insulation which contributed to a reduction of 0.2deg.C and 0.5 deg.C respectively.
  - substituting the existing single glazed windows for double glazed units with external low-e coating, which reduces internal Temperatures by 1.1 deg.C
  - Adding & sizing windows in rooms to allow for cross ventilation, which brought down an average of 1.2 deg.C
  - substituting existing window shading elements with retractable awnings
  - covering the external walls with stone cladding, which reduced the internal temperatures by 2 deg.C
- Increased comfort could be achieved by integrating strategies such as the thermal unit concept, Landscaping and evaporative cooling.

On the other hand, the Ret screen software results show that by using renewable solar power, 44,000 khw and 18,932 khw could be saved annually from water heating , lighting and electrical equipment energy requirements respectively from the application of P.V's and solar water heating panels.

The energy savings achieved provides an example of possible energy reductions from future built environments if a more energy efficient and environmentally sensitive approach to the design is taken.

Environmental optimization is a seemingly simple concept: meet today's needs without reducing the ability to provide for future generations. In ecological terms, this is referred to as not exceeding the carrying capacity of a given ecosystem. Buildings globally account for about 30% of our total energy use and 60% of electricity. In addition, they consume non renewable materials in their construction and operation. By applying sustainable design principles, these environmental loads can be drastically reduced and better environments created.

To conclude, Sustainable desert development is a golden opportunity to learn from our previous mistakes in the cities and develop new, healthier energy efficient communities that would comfort its occupants.



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## 9. Appendices

### 9.1 Appendix 1: Egypt energy sources

Egypt's main energy resources are: oil, natural gas, hydropower and coal. In 2002/2003, crude oil reserves were about 3.682 Billion Barrels of Oil Equivalent, while reserves of natural Gas reached about 10.64 BBOE. (International Energy Agency, 2003)

In 2001/02, the total primary energy production of crude oil, natural gases, coal and hydropower was about 60.490 MTOE ,increased to 61.395 MTOE in 2002/03. Egypt has estimated reserves of 27 million tons coal in Bedah, Eioun Mousa, and Maghara,. Up to 1.8 million tons of Coal are used as a raw materials and iron and steel industries use up it is annually production. The High Dam, Aswan Reservoir, and Esna Station, produce Hydropower energy with installed capacity of 2100 MW, 615 MW, and 90 MW respectively. (Badran et al, 2003)

Egypt has a big potential in Renewable energy resources

. In 2002/2003, the energy consumption from solar resources was approximately 170,000 TOE and 3.8 millions TOE from biomass. (Badran et al, 2003)

Egypt a large capacity of energy production from solar power, with a direct solar radiation reaches 1970-3200 kWh/m<sup>2</sup>/year and it availability throughout the year, covering intensely all regions of the country. Egypt also has significant potential of wind produced energy. wind speed is 11m/s in Gulf of Suez area and 7m/s in east Owainat area, according to the wind atlas for Gulf of Suez region .

Examples of current renewable applications include a hybrid power station using solar parabola concentrators and gas combined cycle of 130 MW at Korimat south of Cairo and the building of wind farms with capacity of 4x100 KW power at Ras Gharib and Hurghada.

The commercial wind farm in Hurghada consists of 42 wind units with total power of 5000 KW, connected to the local electricity grid of Hurghada since 1993. (Badran et al, 2003)

Half million tons of oil equivalent/year will be saved if the target of a capacity of 600 MW by year 2010 is achieved .

Another source of energy, agricultural waste has an energy generating potential of 3.6 MTOE which accounts for about 11% of the total commercial energy consumption. 18 MW biogas power station using sanitary waste as fuel already operational at the Yellow Mountain in Cairo. (Badran et al, 2003)

### National renewable energy sources

Egypt has elaborated more focus on RES to assess the potential for alternative energy and study the practicability of implementing RET for over the past decade. Financing for R&D and the heavy subsidies for energy prices presented hurdles in the way of its wide spread application, even though there was obvious potential for its use

.The funding came from international programs for most of the time to introduce renewable energy application to the Egyptian power generation sector. Never the less, renewables have always been on the governments agenda as a key factor that could eliminate energy subsidies and in order to better utilize it for other development sectors.

### Solar energy

Egypt has a huge potential in generating energy from solar power, according to the 1991 solar atlas, as it has intensities of direct solar radiation ranging between 2000 – 3200 kWh / m<sup>2</sup> / year throughout the country.

. The sun shine duration ranges from 9 – 11 hours with few cloudy days all over the year. Considering the potential of such high solar insolation for power generation or heating processes application. , Egypt is still considered as pre-matured market for solar thermal applications. More wide spread applications are hindered by relatively high initial investment prices and subsidized energy provided by the government for the residential and industrial sectors of Egypt. Despite these obstacles, some initiatives were taken, such as a Solar Thermal Power Plant (150 MW), nearly 90 km South Cairo, wich is proposed and scheduled for operation by 2009. The project site has been selected due to the high intensity of direct solar radiation, reaching 2400 kWh /m<sup>2</sup> / year at that un-inhabited location close to the extended unified power grid and expanded natural gas pipelines and source of water for cooling. (ERC – Final Report December 2006 Renewable Energy Sector in Egypt)



The solar atlas of Egypt below demonstrates high potential for power generation the potential amounted to 73,656 TWh/year, according to the German Aerospace Centre (DLR).

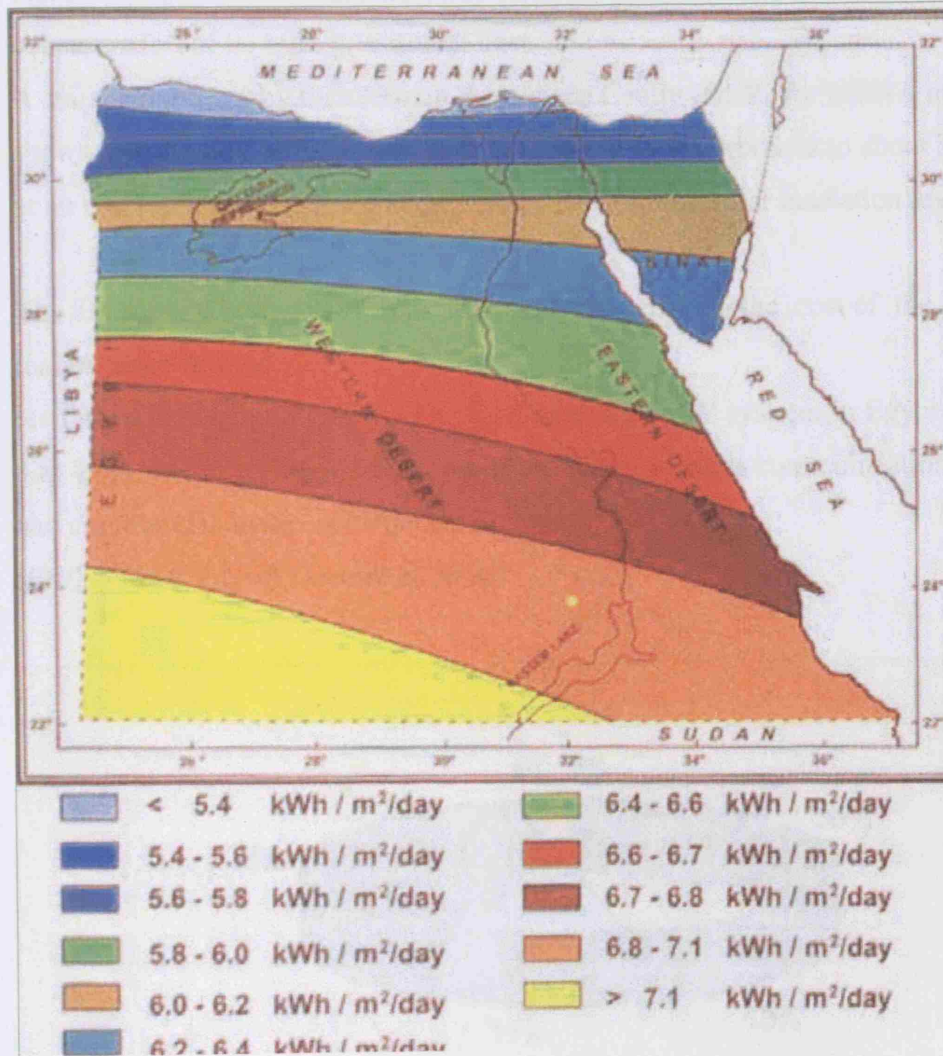


Figure 137: map showing solar energy potential in Egypt

## PV ENERGY

Considering the country's solar potential, and future desert development plans, P.V's would present a very practical option of supplying energy to remote and rural areas that have scattered load and are away from the main national grids, even with the consideration of its high investment cost.

A study conducted by the German Aerospace Centre (DLR) for MENA countries shows that the potential for power generation in Egypt amounts to about 36 TWh/year as an economical potential due the availability of high solar insolation level.

The life span of p.v's is approximately 25 years, making the cost of the systems' maintenance limited.

As shown in the figure below, The total capacity of PV systems in Egypt ranges from 4 to 4.5 MW , covering lighting, water pumping, wireless communications, cooling and commercial advertisements on highways .

(ERC – Final Report December 2006)

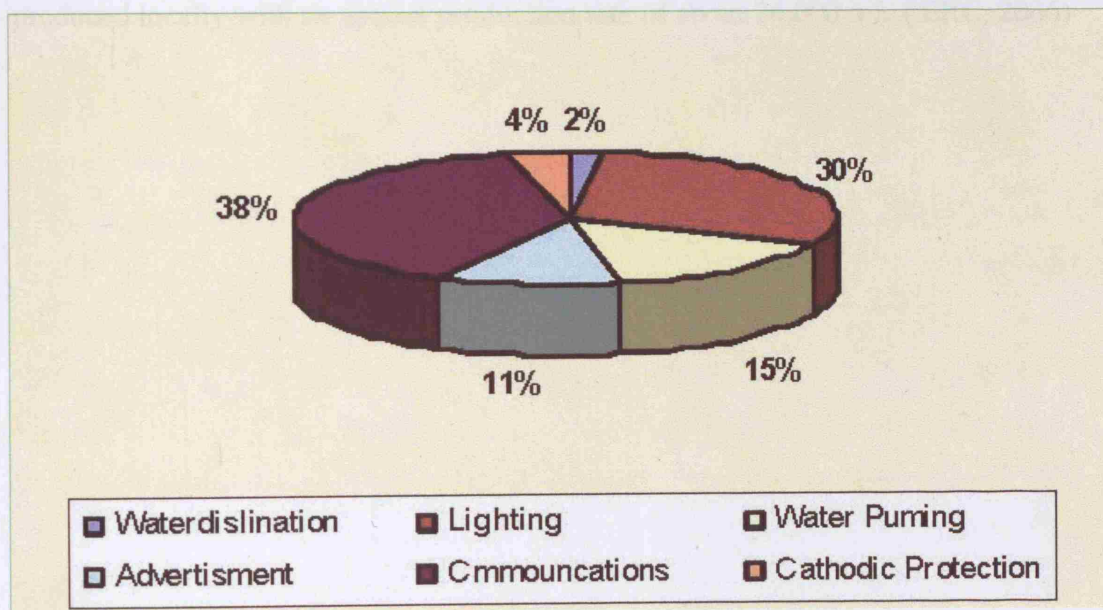


Figure 138 : Distribution of PV Applications in Egypt

## SOLAR THERMAL ENERGY

### Solar Water Heaters

Governmental subsidy for electricity and gas aside, the solar water heaters are fully competitive with conventional water heaters.

Egypt has been manufacturing Solar hot water systems since the early eighties. All necessary components of the system, such as the flat plate solar collectors, the thermally insulated storage tanks as well as connections and piping are produced by the manufactures themselves due to lack of feeding industries.

Open type systems are commonly produced. Two main types of absorber plates were considered. The first type consists of copper risers pressed in grooves of steel absorber plate. (ERC – Final Report December 2006)

The other type consists of two metal sheets and heated water passes in between them. A constant head of few centimetres of water has to be maintained, as the absorber cannot withstand any liquid pressure, even though more uniform temperature is achieved. Hot water tank is always maintained at very low pressure. Both designs are produced locally with an annual production rate of about 24,000 m<sup>2</sup>. ( ERC, 2006)



## 9.2 Appendix 2: Urban desert development



Figure 139: Map of Egypt showing the percentage of the desert to the total land

Roughly 96 percent of Egypt's land mass is made up of desert.

Close to one percent of total arable land is disappearing at a yearly rate of about 74,000 acres (30,000 hectares), as urbanization is taking up Prime agricultural land in the valley and delta (Stanek, 2008)

The two figures below show significant agricultural land depletion for two projected alternatives of continuous urban growth at the expense of agricultural lands. Within fifty years, or by the end of this century, if development efforts and expansion outside Egypt's populated areas succeed, both figures show complete loss of old agricultural lands,. These scenarios require serious study and quick action of the issue to ensure that such expectations do not come true.

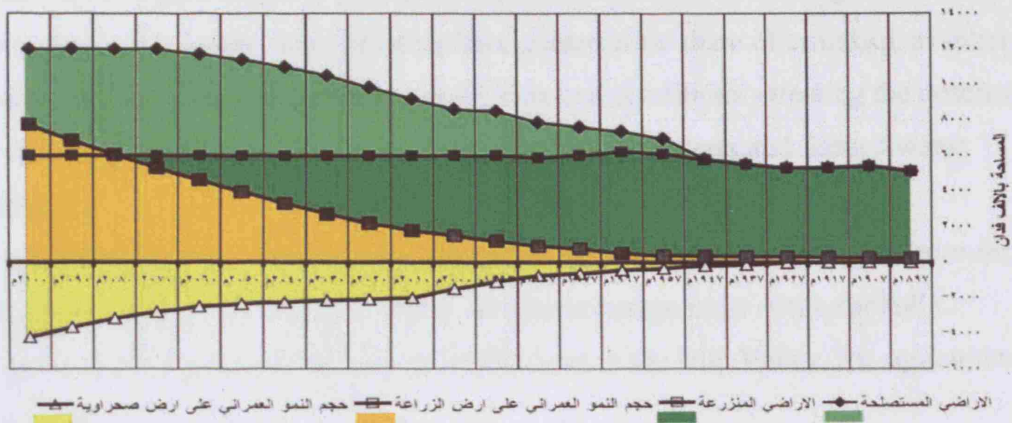


Figure 140: agricultural land depletion in Egypt in 50 years

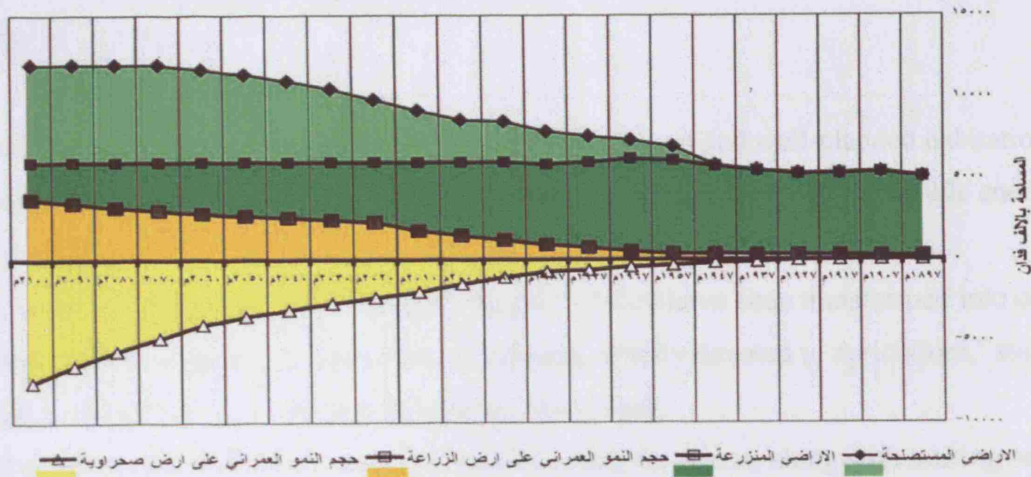


Figure 141: agricultural land depletion in Egypt by the end of the century

The Nile Valley and Delta is occupied by roughly 95 percent of Egypt's 80 million population, which presents the country's most habitable land but presents less than 5 percent of its landmass.

Egypt aspires to move large numbers of people to new urban communities outside the Nile Basin by reclaiming the desert, where they can find jobs and houses and help the country achieve food security. (Stanek, 2008)

Desert development is a crucial move as the population grows by about 1.5 million people per year, and population density reaches up to 4,900 people per square mile (1,900 people per square kilometer) in the cities, ( Stanek, 2008)



Although a large number of projects have been initiated to extend agricultural activities in the desert, these projects have gained their share of criticism, as other voices call for adaptation to desert environmental conditions - treating the desert as a desert, claiming that there are better uses for Egypt's deserts and limited water resources.

A noted Egyptian geologist, Rushdi Said has argued that it would be "smarter for Egypt to urbanize its deserts", which would encourage most of the capital's population to move out, clearing the fertile land of the Nile Valley, for agricultural activities.

The argument has its appeal, as the land of the Nile Valley is among the most productive in the world and yields twice the amount of crops of the desert farmlands, and that most experts agree that the desert will never be an ideal place to farm. (Stanek, 2008)

"I envision the deserts of Egypt strewn with well-spaced and well-planned habitation centers, built around extensive industrial bases and fuelled by locally available energy resources."

"It is an Egypt in which the Delta and the Nile Valley have been transformed into one great garden—a natural reserve free of industry, wholly devoted to agriculture," said Said, according to the state-run Al-Ahram newspaper.

Others plans proposed by experts include devoting the desert, along with hosting new urban communities, to ecotourism, which is a booming industry in Egypt. Another plan was using the desert to host renewable energy projects, such as building giant solar panels and wind farms to create energy.

### 9.3 Appendix 3: Internal & external Shades

#### Internal Moveable shades

Internal shades can be highly effective in reducing solar gains but have the disadvantage of limiting views and air movement, e.g., roller blinds, curtain, etc. For instance, Blinds could be an effective means to reduce cooling load, effects of direct radiation on occupants, and glare, but if used with a naturally ventilated building, they can strongly limit the effective movement of air.

The reflectivity of the fabric depends of the material used and its colour, and is the main factor for the elements efficiency. Generally the lighter the fabric's colour, the more reflective it is. However, care should be taken as light coloured fabrics also transmit high levels of radiation. Selecting very dark colours can prove to be problematic as well, as they absorb a lot of heat.

Aluminiumized finished fabrics present an optimum option. These are highly opaque but still look light coloured from the inside of the building when illuminated from inside. (Square one software, 2007)

### Examples of internal shades

#### Curtains and drapes

Curtains and Draperies can be an effective tool in reflecting short wave solar radiation back. They are usually made of light coloured, tightly woven, opaque fabrics. To better prevent heat gain, the curtains should be placed tighter against the wall around the windows. To improve the effectiveness of the draperies, two distinct layers are usually used for insulation from hot or cold outside temperatures.

#### Venetian blinds

Blinds have the advantage of being adjustable to let in some air and light as well as reflecting heat. If the blinds are coated with reflective finishes, their efficiency increase.

#### Cellular Shades

Cellular or honeycomb shades are effective in increasing the thermal resistance of the overall window as they are made from two layers of material with an air-gap between, allowing them to be raised and lowered easily. For increased effectiveness, interior cellular shades also come with a reflective mylar coating.

## External Shading devices

External shades block solar radiation before it enters the window, which is an advantage over more internal shades.

External shades May be removable, adjustable, or fixed-affect view and air movement to some degree. External shading devices include awnings, louvers, shutters, rolling shutters and shades, and solar screens. One of the most important external shading devices is the building form itself. The building form can be designed in a way that protects it's openings that may otherwise be exposed to direct sun. Examples include Balconies and inset windows.

### Examples of external shading devices

#### Awnings

They are usually made out of fabric or metal and can retract down and out, which can maximize winter heat gains. Awnings completely block direct sunlight in the summer. When properly installed, they can reduce heat gains substantially up to 77% on eastern windows and 65% on northern windows.

Awnings also contribute in reducing temperatures by reflecting radiation, if the fabric used is a light colour.

The awning could open out and down depending on the orientation. . An east or west window needs a drop of at least 65% to 75% of the window height. A north-facing window needs only a drop of 30% to 50% for the same amount of shade. A pleasing angle to the eye for mounting an awning is around 45 degrees The disadvantage of awnings is that they could limit the view , but that could be resolved by using slatted awnings . (Square one, 2007)

#### Solar screens

Solar screen are fitted externally to the outside of the frame. They have an advantage of cutting down the amount of sun light entering the window and glare without eliminating the air flow or blocking out the view. further reduction of solar rays could be achieved by using partially reflective screens. (Square one, 2007)

### louvers

Louvers can be very effective, as their adjustable slats control sunlight levels entering the building and can be manually or automatically adjusted from inside or outside. .

The slats can be vertical or horizontal.

Angle adjustments to the louver can allow favourable winter sun in while still excluding unwanted summer sun penetration.

### Shutters

Shutters consist of openable wooden or metal coverings that keep sunlight out when they are closed. Shutters have two main advantages: 1) when closed they can provide security and privacy 2) some shutters help insulate windows when the external temperature is cold.

### Roller Shutters

Roller shutters consist of series of horizontal slats that move along a track. They provide effective solar reduction and security and have the advantage of being conveniently controlled from inside, but have the drawbacks of blocking all light and view when fully extended and are considered the most expensive shading option. Many exterior rolling shutters or shades can be conveniently controlled from the inside. (Square one, 2007)

### Fixed overhangs

Examples of fixed overhangs are balconies or overhanging roofs.. They have the advantage of giving protection to walls and openings from rain. And have minor or no effect on view and air movement.

## 9.4 Appendix 4: Passive solar heating systems:

### Direct gain

In direct gain the mass of the building fabric acts as the thermal storage material, storing the excess solar energy to heat spaces at night when it is released. The sun enters the room through windows or skylights and the radiation reach the thermal storing mass directly or after it reflects from other surfaces.

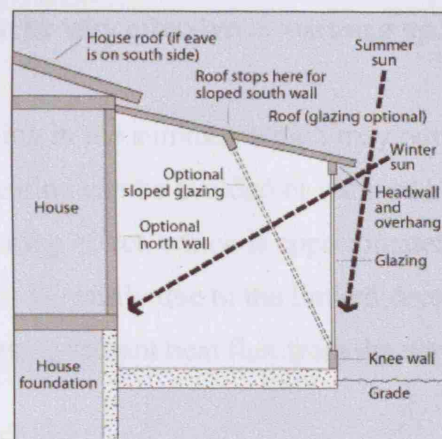


Figure 142: Direct gain

(source: [www.engineering.com/portals/0/images/sunspace.gif](http://www.engineering.com/portals/0/images/sunspace.gif) )

When applying direct gain to heat spaces some factors have to be considered, such as the size, type, location and orientation of the solar glazing. The total heat loss coefficient of the building also has to be considered as well as the thermal coupling between solar and non solar rooms. Lastly, the arrangement of the furniture in the 'solar' rooms and the control options of heat gain and loss through the glazing. (Givoni, 1997)



## Collecting Storage (Trombe) walls

Trombe walls consist of two main elements, a thermally massive wall and a glazing layer. The wall layer is painted dark to maximize the absorption of solar radiation. Solar radiation passes through the glazing and is absorbed in the wall, raising its temperature which, in return, raises the temperature of the adjacent internal spaces. The glass stops the heat gained from escaping, trapping it inside the small air gap created between the glazing and the wall, which in return further heats the wall. Another advantage of trombe walls is that they can be load bearing, carrying floors and ceilings.

Although trombe walls can be very effective in warming up spaces, they do have some disadvantages:

- They can cause overheating in the summer, which may outweigh its heat storing winter advantages. Overheating can be avoided or reduced by applying shading.
- there is a limit to its heating effect, which is approximately one and one and a half times the wall's height. This is mainly due to the limited depth of natural convection air currents and the decreasing radiant heat flux from the warmed sun-facing wall.

The trombe wall's performance is affected by the following factors:

- 1) Materials: Materials of relatively high thermal conductivity are important in allowing optimal energy transfer through walls. Examples of favourable materials include concrete, solid concrete blocks or dense bricks. Low conductivity materials, such as adobe and light weight concrete should be avoided as they would result in lowering the efficiency.
- 2) Wall thickness: There is a lag of about 2-2.5 hours for each 10cm of concrete between peak solar absorption, and heat delivery at the inside.

(Givoni, 1997)

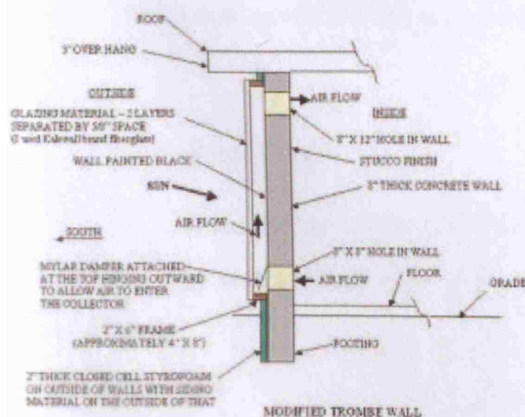


Figure 143 & 144 : Examples of trombe walls (Source: , )

### Sun spaces

Sun spaces are internal usable spaces that are positioned between the interior of the house, and its exterior. They contribute in lowering the internal temperatures because they serve as a 'thermal transition; space in the house, separated from the main living rooms. They become very pleasant spaces in the winter season, as the amount of glazing is larger than what a direct gain window would allow. The increased glazing allows for more heat collection. They could be covered in the winter by shades or louvers to shield the internal spaces from increased solar radiation., (Givoni, 1997)

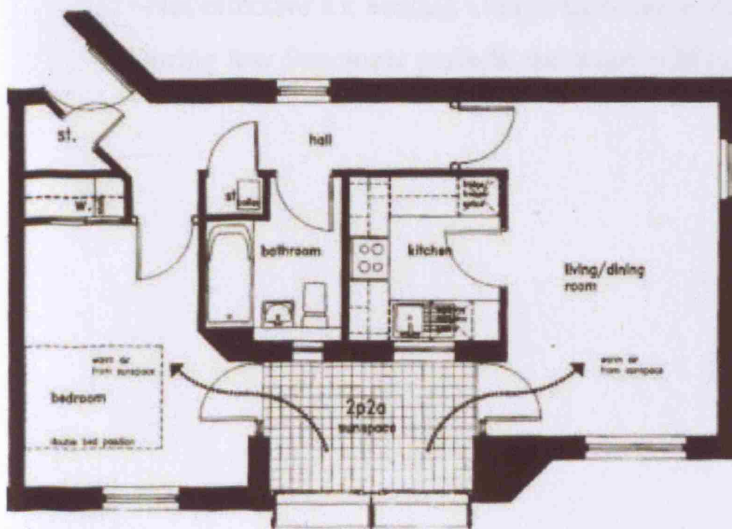


Figure 145 & 146 : Examples of sunspaces (source: [http://www.archive2.official-documents.co.uk/document/deps/cs/shdg/img/c11fig11.02\\_lrg.jpg](http://www.archive2.official-documents.co.uk/document/deps/cs/shdg/img/c11fig11.02_lrg.jpg) , [www.daviddarling.info/images/sunspace.jpg](http://www.daviddarling.info/images/sunspace.jpg) )

### Roof Ponds

A roof pond can be used to provide heating. Solar radiation is absorbed during the day by water stored above the roof. The water is covered at night with insulating panels to

prevent absorbed heat from escaping. The stored heat warms up the ceiling and radiates down into the space below. No convection current is created, however, as the warmest air tends to remain beneath the ceiling.

The closeness of the ceiling to the occupants being warmed is important, as the distribution of collected heat is by radiation only, and the density of radiation drops off quickly with distance.

In order to maximise solar collection, the water stored in the roof pond is contained within black surfaces. Uniform low-temperature heat will radiate to the entire layout in both sunny and cloudy conditions, since thermal storage is the ceiling of the building

Important considerations:

- The load of the water has to be calculated and supported by an adequate structure.
- A thin conducting ceiling immediately below, preferably with ridges or corrugations to increase its interfacing surface area.
- Not effective for heating at high latitudes as the

During low Sun angle periods, the water will not be heated effectively. (Square one)

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